PROCEEDINGS

OF THE

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HELD AT PHILADELPHIA

FOR

PROMOTING USEFUL KNOWLEDGE

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ABSTRACTS FROM THE MINUTES OF THE MEETINGS

DURING 1933

Stated Meeting, January 6, 1933

ROLAND S. MORRIS, LL.B., LL.D., D.C.L., President in the Chair

A letter of appreciation of the Society's action in sponsoring the International Catalogue of Scientific Literature was received from Dr. Charles G. Abbot, Secretary of the Smithsonian Institution.

The decease was announced of the following members:

Henry G. Bryant, M.A., LL.B., at Philadelphia, December 7, 1932, æt. 73.

William S. Thayer, M.D., LL.D., Sc.D., at Baltimore, December 11, 1932, æt. 68.

William J. Holland, Ph.D., Sc.D., D.D., LL.D., L.H.D., at Pittsburgh, December 13, 1932, æt. 84.

John F. Lewis, LL.D., at Philadelphia, December 24, 1932, æt. 72.

John J. Carty, D.Sc., LL.D., at Baltimore, December 27, 1932, æt. 71.

Eliakim H. Moore, Ph.D., LL.D., Sc.D., Math.D., at Chicago, December 30, 1932, æt. 70.

The following papers were read:

"The Future of Reform as Indicated by the Past," by Edward P. Cheyney, LL.D., Henry C. Lea Professor of History, University of Pennsylvania. Discussed by Drs. E. M. Patterson, W. E. Lingelbach and Em. R. Johnson.

"Some Notes Upon the Nature, Health and Mainte-

nance of the Hyrax," by Herbert Fox. (Read by title.)

"Marine Fossils from New Jersey Indicating a Mild Interglacial Climate," by Horace G. Richards. (Introduced by Dr. Pilsbry.) (Read by title.)

Stated Meeting, February 3, 1933

JOHN A. MILLER, Ph.D., LL.D., Secretary in the Chair

The decease was announced of the following members:

Dana C. Munro, L.H.D., at Princeton, New Jersey, January 13, 1933, æt. 67.

Eli Kirk Price, LL.B., at Philadelphia, January 24, 1933, æt. 72.

On motion the members and guests by a standing vote expressed the deep appreciation of the Society for Mr. Price's many years of generous and valuable service to the Society.

The following papers were read:

"Spirals and Theories of the Expanding Universe," by Heber Doust Curtis, Ph.D., Sc.D., Director of the Detroit Observatory.

"Archeological Discoveries in the Mayan Area," by Cyrus Longworth Lundell. (Introduced by Dr Bartlett.) (Read by title.)

Stated Meeting, March 3, 1933

ROLAND S. MORRIS, LL.B., LL.D., D.C.L., President in the Chair

The decease was announced of the following member:

Henry Willis, A.M., at Philadelphia, February 18, 1933, æt. 81.

The following paper was read:

"Reparations and Other War Debts in Theory and Practice," by Ernest Minor Patterson, Ph.D., Professor of Economics, University of Pennsylvania.

Discussed by President Morris and Drs. Johnson and Swann.

William P. Gest was elected Treasurer to fill the vacancy created by the death of Eli Kirk Price.

General Stated Meeting, April 20, 21, 22, 1933

Thursday Morning, April 20th

Opening Session—9:30 o'clock

ROLAND S. MORRIS, LL.B., LL.D., D.C.L., President in the Chair

A letter was received from Elihu Thomson thanking the Society for the testimonial sent to him on the occasion of his eightieth birthday.

The decease was announced of the following member:

William Cawthorne Unwin, LL.D., F.R.S., at London, March 17, 1933, æt. 94.

In memory of Eliakim H. Moore the following minute was adopted: That American mathematics has lost one of its important figures; that as an investigator of great originality, as an inspiring guide to many younger mathematicians, as a leader in the organization of the mathematical resources of this country, he has made an outstanding contribution to the development of mathematics.

The President delivered his Annual Report.

Special Meeting, 11 o'clock

ROLAND S. MORRIS, LL.B., LL.D., D.C.L., President in the Chair

As a tribute to the life achievements of R. A. F. Penrose, Jr., Waldemar Lindgren, M.E., Sc.D., William Barton Rogers Professor of Economic Geology, Massachusetts Institute of Technology, spoke on Dr. Penrose's contributions and generous benefactions to the Science of Geology.

In memory of William Williams Keen, for ten years President of the American Philosophical Society, William Darrach,

M.D., Sc.D., LL.D., New York, spoke on Dr. Keen as a Promoter of Useful Knowledge.

Thursday Afternoon, 2 o'clock

ROLAND S. MORRIS, LL.B., LL.D., D.C.L., President in the Chair

Sewall Wright, Elmer D. Merrill, William Darrach and George Grant MacCurdy, recently elected members, subscribed the Laws and were admitted into the Society.

The following papers were read:

"An Unusual Chimæra," by William Trelease, formerly Professor of Botany, University of Illinois. (Read by title.)

"Loureiro and His Botanical Work," by Elmer D. Merrill, Professor of Botany, Columbia University.

"The Relation of Leaf-Surface to Wood-Formation in Pine Trees," by D. T. MacDougal, Research Associate, Carnegie Institution of Washington. (Read by title.)

"Some Problems of Plant Distribution in Eastern North America," by Francis W. Pennell, Academy of Natural Sciences. (Introduced by Dr. Pilsbry.) (Read by title.)

"Further Studies in the Transfer of Neurohumoral Substances," by G. H. Parker, Professor of Zoology, Harvard University. Discussed by Dr. Conklin.

"On the Classification and Interpretation of Certain Types of Abnormal Development of the Head in Vertebrates," by Sewall Wright, Professor of Zoology, University of Chicago.

"Host-Parasite Relations between Parasitic Protozoa and Their Hosts," by David Henry Wenrich, Professor of Zoology, University of Pennsylvania. (Introduced by Dr. McClung.)

"Human Gaseous Metabolism in Atmospheres of Pure Oxygen," by Francis G. Benedict, Director of the

Nutrition Laboratory, Carnegie Institution of Washington, and Robert C. Lee.

Friday Morning, April 21st
Executive Session—9:30 o'clock

Roland S. Morris, LL.B., LL.D., D.C.L., President in the Chair

The Proceedings of the Council were submitted and the nominees were recommended for election.

The report of the Committee on Policy was presented by John C. Merriam which was discussed and adopted with amendments. Under "Use of Funds for the Advancement of Knowledge through Investigation," the Committee specifically recommended "That there be set aside from the funds of the Society an amount not less than $20,000 per year to accumulate as a fund for use in the advancement of knowledge through investigation, with the assumption that plans for the development of the meetings and work of the Society as described would be considered in the use of this fund.

The Fidelity-Philadelphia Trust Company was elected Treasurer for the ensuing year.

The Society proceeded to an election of officers and members.

The tellers subsequently reported that the following officers and members had been duly elected:

President

Roland S. Morris

Vice-Presidents

Elihu Thomson
Edwin G. Conklin
Alba B. Johnson

Secretaries

Arthur W. Goodspeed
John A. Miller

Curator

Albert P. Brubaker

Councillors

(To serve for three years)

Frank Schlesinger
Edward W. Berry
Frank P. Graves
Gilbert A. Bliss

Members

Donald H. Andrews
William Bell Dinsmoor
Edward Vermilye Huntington
Burton E. Livingston
Edward Martin
Marshall S. Morgan
G. Kingsley Noble
Francis Randolph Packard
Samuel Price Wetherill, Jr.
Westel Woodbury Willoughby
James Thomas Young

Foreign Members

James Colquhoun Irvine
Max Planck

Morning Session—10 o'clock

Edwin G. Conklin, Ph.D., Sc.D., LL.D., Vice-President in the Chair

The following papers were read:

"Prehistoric Research in the Near East," by George Grant MacCurdy, Research Associate in Prehistoric Archæology and Curator of the Anthropological Collections, Yale University. Discussed by Dr. Albright.

"The Fish Fauna of Beartooth Butte, Wyoming," by W. L. Bryant, Director of the Park Museum. (In-

troduced by Dr. Sinclair.) Discussed by Drs. Sinclair, Conklin and Scott.

"American Eusmiloid Sabre-tooth Cats of the Oligocene Epoch," by Glenn L. Jepsen, Princeton University. (Introduced by Dr. Sinclair.) (Read by title.)

"Progressive Chondrification in the Stegocephalia," by Ermine C. Case, Professor of Paleontology, University of Michigan.

"Hematite Deposits and the Unconformity at the Base of the Cambrian in New York and New Jersey," by A. F. Buddington, Associate Professor of Geology, Princeton University.

"Atlas of the Historical Geography of the United States," by John K. Wright, Librarian, American Geographical Society. (Introduced by Dr. Bowman.) Discussed by Drs. Leland and Parker.

"Inhibiting Factors in Shepherd's-Purse," by George H. Shull, Professor of Botany and Genetics, Princeton University.

"The Forehead: Its Esthetic and Anthropological Values," by Aleš Hrdlička, Curator, Division of Physical Anthropology, U. S. National Museum, Smithsonian Institution. Discussed by Drs. Benedict, Parker, W. B. Scott, Goodspeed, Phelps and Humphreys.

Afternoon Session—2 o'clock

CYRUS ADLER, M.A., Ph.D., D.H.L., Litt.D.,
in the Chair

The following papers were read:

"Jivaro Shamanism," by Matthew W. Stirling, Chief, Bureau of Ethnology, Smithsonian Institution. (Read by Dr. Hrdlička.)

"A New Source of Knowledge for Ancient Hebrew, namely the Ras Shamra Texts," by James A. Montgomery, Professor of Hebrew, Graduate School, University of Pennsylvania.

"The Transition from Prehistory to History as Illustrated at Tepe Gawra," by Ephraim A. Speiser, Assistant Professor of Semitic Languages, University of Pennsylvania. (Introduced by Dr. Barton.)

"Archæology and the Dark Age of Classical Greece," by Rhys Carpenter, Professor of Classical Archæology, Bryn Mawr College. (Introduced by Dr. Barton.)

"American Excavations in Jugoslavia, Seasons 1931–1932," by Vladimir J. Fewkes, Director of the Harvard-American School of Prehistoric Research. (Introduced by Dr. Hooton.) (Read by title.)

"Queen Elizabeth's Seizure of the Duke of Alva's Pay-Ships," by Conyers Read, Executive Secretary, American Historical Association. (Introduced by Dr. Lingelbach.)

"History of the Preliminary Examination of Accused Persons in England," by Edwin Roulette Keedy, Professor of Law, Law School of the University of Pennsylvania. (Introduced by Dr. Sioussat.)

"Robert Browning and Spiritualism," by William Lyon Phelps, Professor of English Language and Literature, Yale University.

"Orthogenesis and the Power and Infirmities of Man," by George W. Crile, Director of the Cleveland Clinic and of the Cleveland Clinic Hospital.

Friday Evening Lecture

Alfred V. Kidder, Chairman of the Division of Historical Research, Carnegie Institution of Washington, spoke on "Mayan Explorations and Their Results."

Saturday Morning, April 22nd

Morning Session—10 o'clock

ELIHU THOMSON, A.M., Ph.D., D.Sc., LL.D., Vice-President in the Chair

Gilbert A. Bliss, Hugh S. Taylor, Vesto M. Slipher,

George L. Hendrickson, Irving Langmuir, Edward C. Armstrong, James T. Young and William F. Osgood, recently elected members, subscribed the Laws and were admitted into the Society.

The following papers were read:

"Magnetic Definitions from the Circuital Standpoint," by Arthur E. Kennelly, Professor of Electrical Engineering, Harvard University. Discussed by Dr. Swann.

"Heights and Train-drifts of the Leonid Meteors of 1932," by Charles P. Olivier, Professor of Astronomy and Director of the Flower Observatory, University of Pennsylvania. Discussed by Drs. Scott, Thomson, Miller and Humphreys.

"The Spectrum of the Night Sky and Its Cosmic Radiations," by Vesto M. Slipher, Director of the Lowell Observatory. Discussed by Drs. Russell and Humphreys.

"Recent Advances in Mathematics," by George D. Birkhoff, Professor of Mathematics, Harvard University. Discussed by Drs. Dresden, Miller and Swann.

"Cosmic Ray Ionization," by W. F. G. Swann, Director of the Bartol Research Foundation.

"Activated Adsorption of Hydrogen on Tungsten," by Irving Langmuir, Research Laboratory, General Electric Company.

"The Calculation of the Speed of Chemical Reactions," by Henry Eyring, Princeton University. (Introduced by Dr. H. S. Taylor.)

"Atomic and Molecular Hydrogen as Revealed by Processes at Surfaces," by Hugh S. Taylor, Professor of Chemistry, Princeton University. Discussed by Dr. W. B. Scott.

"Further Experiments on the Continual Generation of Heat in Certain Silicates," by Elmer A. Harrington, Associate Physicist, U. S. Bureau of Standards.

Afternoon Session—2 o'clock

ROLAND S. MORRIS, LL.B , LL.D., D.C.L., President in the Chair

The following Symposium on "The Organization and Functioning of Government" was presented:

"The Growing Overhead in Government," by James T. Young, Professor of Public Administration and Chairman of the Department of Political Science, University of Pennsylvania. (Introduced by Dr. Johnson.)

"Reorganization of Local Government," by Harold W. Dodds, Professor of Politics, Princeton University. (Introduced by Dr. Johnson.)

"Structural Improvements in the Administration of the Foreign Affairs of the United States Government," by D. C. Poole, Chairman, Advisory Board of the School of Public and International Affairs, Princeton University. (Introduced by Dr. Johnson.)

"Recent Development of the Amending Power as Applied to the Federal Constitution," by Herman V. Ames, Professor of American Constitutional History, University of Pennsylvania. Discussed by President Morris.

Saturday Evening

The annual dinner was held at the Bellevue Stratford Hotel. Roland S. Morris presided and the toasts responded to were as follows:

"Our Sister Societies," John H. Finley
"Franklin," Edward P. Cheyney
"Our Universities," Frank P. Graves
"The American Philosophical Society," Roland S. Morris

Special Meeting, October 12, 1933

ROLAND S. MORRIS, LL.B., LL.D., D.C.L., President in the Chair

Edward Martin and Charles Phelps Smyth, recently elected members, subscribed the Laws and were admitted into the Society.

The decease was announced of the following members:

Zelia Nuttall, at Mexico City, on April 12, 1933, æt. 75.

John Chalmers DaCosta, M.D., LL.D., at Philadelphia, on May 16, 1933, æt. 70.

Cyrus H. K. Curtis, at Philadelphia, on June 7, 1933, æt. 83.

Sir Herbert Samuel, P.C., G.C.B., G.B.E., Secretary of State for Home Affairs, 1931–32, Member of Parliament and Leader of the Liberal Party, spoke on "Why the London Economic Conference Failed." Discussed by Drs. Em. R. Johnson, Kemmerer and E. M. Patterson.

Stated Meeting, November 3, 1933

ALBA B. JOHNSON, A.B., LL.D., Vice-President in the Chair

Donald H. Andrews, recently elected member, subscribed the Laws and was admitted into the Society.

A letter was received from Thomas C. Poulter, Physicist of the Byrd Antarctic Expedition II, thanking the Society on behalf of Admiral Byrd for its contribution of $3,000 to pay for the Echo Sounding Equipment in connection with the Scientific Program of the Expedition, and stating that he would be very glad to present the results of the investigations made on the expedition before the Society and also to offer them for publication in the Proceedings.

The decease was announced of the following member:

Edward Higginson Williams, Jr., B.A., B.S., E.M., Sc.D., LL.D., in Woodstock, Vt., November 2, 1933, æt. 84.

The following papers were read:

"A New Marsupial Sabre-Tooth from the Pliocene of Argentina and its Relationships to the South American Sparassodonts," by E. S. Riggs, Field Museum of Natural History, Chicago, presented by William B. Scott, M.A., Ph.D., Sc.D., LL.D., Princeton, N. J. Discussed by Drs. Schaeffer, Donaldson and Prof. Chester Stock.

"The Fish Fauna of Beartooth Butte, Wyoming," Parts II and III, by W. L. Bryant, Director of the Park Museum. (Introduced by Professor Sinclair.) (Read by title.)

Stated Meeting, December 1, 1933

ROLAND S. MORRIS, LL.B., LL.D., D.C.L., President in the Chair

James Bond, Research Associate, Department of Vertebrate Zoology, The Academy of Natural Sciences of Philadelphia, read a paper on "The Origin and Distribution of the Avifauna of the West Indies." Discussed by Drs. Scott, Stone, Calvert, Miller and a guest, Mr. Rehn.

It was unanimously resolved to present Volume 3 of "Selections from the correspondence of the Honourable James Logan" to The Historical Society of Pennsylvania. As that society now owns the other four volumes of the set, it seemed appropriate to take this action.

At the suggestion of President Leith of the Geological Society of America that representatives be appointed from our "Projects Committee" to confer with a similar committee of the Geological Society concerning certain interrelations of the two societies, as for example "atomic disintegration and related phenomena," the President appointed Drs. Scott and Conklin as our representatives.

The minutes of the Stated Meeting of the Council held on November 17th were read and approved as corrected.

The dates of the Annual General Meeting, April 19, 20, 21, 1934, were formally ratified.

PROCEEDINGS

OF THE

AMERICAN PHILOSOPHICAL SOCIETY

HELD AT PHILADELPHIA

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VOL. 72 1933 No. 1

SOME NOTES UPON THE NATURE, HEALTH AND MAINTENANCE OF THE HYRAX[1]

HERBERT FOX

(*Read by title January 6, 1933*)

THE unusual character of the hyrax, its relative paucity in exhibitions in this country, its peculiar zoological position and its rather short period of life in captivity combine to make it an interesting object of study. In addition, it has failings of health that depend upon unnatural surroundings and, to no small extent, upon its anatomical constitution. In the following pages will be found a survey of the specimens studied in our laboratory, attempting to present the character of the animal and to indicate preservative and health measures designed to lengthen life and encourage propagation.

The hyrax is a beast about the size of a rabbit and in captivity, when adult, weighs from three to five pounds. It has relatively small round, standing ears, not pointed and stiff as in the hare. The muzzle is pointed but delicately split as in the hare. The body is covered with rather stiff, moderately long fur of a gray-brown color subject to variations according to species. Its habitat is Africa, from the equatorial regions to the cape, and southwestern Asia.

[1] From the Laboratory of Comparative Pathology, Philadelphia Zoological Society, Philadelphia.

This odd little animal has been known since antiquity. The word hyrax is of Greek origin and means shrewmouse. The name seems to have been used first by Herman who indicated its generic character. Its outstanding historical reference seems to be found in the Bible where according to the authorities Kingsley and Flower the beast is alluded to in Leviticus xl. 5: "And the coney, because he cheweth the cud, but divideth not the hoof; he is unclean to you." Kingsley states that the same thought is found in Deuteronomy xiv. 7, and in the Psalms civ. 18: "The rocks of the high hills are a refuge for the conies." In Proverbs the following quotation will be found, "There be four things which are little upon the earth, but they are exceeding wise; the ants are a people not strong, yet they prepare their meat in the summer; the conies are but a feeble folk, yet they make their houses in the rocks; the locusts have no king, yet they go forth all of them by bands; the spider taketh hold with her hands, and is in the kings' palaces." The coney is quite different from the other particularized things although it has only the size of a rabbit.

In great part the descriptions suggested in the scriptures permit us to recognize the animal we are interested in but Kingsley calls attention to the fact that there is one suggestion of error, that of rumination which the hyrax does not perform. Flower and Chalmers Mitchell call attention to the word cirogrille and its variants cherogril, chirogrylle, and choerogryl. The first was apparently used by Wyclif in 1388; at that time it implied a little pig and probably refers to the Syrian form. The Dutch colonists, where the animal lives, called it Klipdaassie or rock badger. It was also called a marmot by Kolbe. It has no truly equivalent English name.

The animal was originally put close to the elephants because of the large bulge of the anterior maxillary skull, the posterior position of the malar bones, the character and the position of the teeth, and the close junction of the four toes. It was left to Huxley to observe the justice of putting this into a separate group, albeit near the ungulates. The classification depends upon the development of both upper and

lower incisors, the flatness of the malars permitting a partially rotary mastication, the hoof-like termination of the nails of the toes and the character of the hairs which are bristly.

Many species have been recognized but only three are recorded by the last Catalogue of the London Zoölogical Society. Their differentiation depends upon their habitat, color and length of fur over their capital, cervical and caudal regions. The three species seem to be fairly well confined to their particular habitat. One group lives in southern Africa, another in southwestern Asia and another in middle west Africa. The last zoölogical classification puts them in the order Hyracoidea, the family Procaviidæ, a single genus Procavia of three species *capensis*, *syriaca* and *dorsalis*.

The Cape Hyrax lives among the rocks from sea level to ten thousand feet and shelters itself in caves and nooks and feeds chiefly at night and early morning upon buds and tender foliage. I do not find a reference to the feeding by these small animals upon insects but I would think that from the grinding power of the molars and the relatively stout gastric wall they should be able to eat such protein material that could be macerated. We have no data concerning the digestive juices of these animals, which leads one at this point to the observation that information concerning the digestive possibilities of most animals is not at hand.[1] Continuing with observations on the masticatory powers and considering the wall of the stomach, it is interesting to note that there is in the cardiac region extending from the esophageal opening, a roughened or papilloid thickening of the mucosa. This peculiarity is discussed at length on a later page.

The Arabian or Syrian form is much the same but according to legend its habit of sitting up with a hunched back and working its jaws has such a similarity to the behavior of the rabbits that it was called the rock rabbit. The western form

[1] The construction of the teeth, stomach wall and intestinal tract are accommodated to the ordinary dietary intake, but this should not be a final argument that the potentiality of the digestion may not or could not extend to other or all varieties of food. The writer is strongly of the opinion that the baboon does not have his denture simply for protection, but that be can and probably will employ it for the crushing of heavy types of protein food.

is a somewhat sturdier beast, perhaps lives less openly in rocky places, even climbing trees. In behavior all hyraces are nervous, quick, darting in action, quickly apprehensive of anything unusual and scooting with great agility and speed at the slightest unusual change. They have a very shrill call said to be unlike that of any other animal.

These animals appear to run in communities and squat or lie together in groups on open rocky places. The writer is obliged to wonder as to the value of the group since these animals seem not to have any true communistic spirit of mass protection or feeding assistance such as obtains in some other varieties. They seem not to be agressive toward other animals. Bigalke writes that hyraces are inclined to be quarrelsome under both natural and captive condition and that full-grown adults may inflict fatal injuries upon young ones.

A knowledge of breeding seems to be limited to specimens in private collections. Young are born in groups as are the rodents. They have a placentation something like the elephant. Judging by the experience in London and Cairo they can be born in captivity and kept for a moderate time.

There are certain anatomical features peculiar to the hyrax that may or may not have something to do with its maintenance under captive condition or its health and longevity.

The rather long curved incisors, one pair above and two pairs below, grow from a persistent pulp so that they can keep on growing. The upper ones are slightly convex anteriorly; some writers have called them semicircular incisors. They taper from the insertion to the tip which is quite narrow. The molars, seven on each side of both upper and lower jaws, are originally mammated but become smooth to the usual appearance of those of the rhinoceros. There are no true canines although there is reported in extinct species a somewhat molar-like tooth in the space now free between the incisors and the molars.

Externally the most prominent hairs are seen about the eyes and rump. The tail is so abbreviated that there is a mere suggestion of it. The feet have pads extending to the

toes and there is a distinct elephant suggestion in the broad short nails of all the digits except the inner one on the hind foot which is furnished with a long curved claw. On the fore-foot the fifth toe is present but the first is rudimentary, while on the hind-foot the fifth is rudimentary and the first absent.

The ribs, numbering nineteen or twenty pairs (one of our specimens had twenty-one pairs), are normally quite delicate and seem to consist, under conditions seen in a menagerie, of a very delicate cortex and extensive spongy interior. This makes it somewhat difficult to determine the early stages of bone degeneration. The sternum, consisting of six sections, receives seven or eight of the ribs. There is no clavicle and no acromion.

There is a very prominent gland in the rump, its location being indicated by some differentiation of fur color. Most hyraces have three pairs of mammae; one reference states that *sp. dorsalis* has a single pair. The internal peculiarities of anatomy other than those suggested in the forgoing are best illustrated in the detailed notes of the cases at this Laboratory given below, which represent analyses of individual histories and protocols; this is followed by a discussion of the entire series.

P. capensis ♀, 2715. 2–17–12—9–15–12. Adult.

Only history indicates increasing inability to move the limbs dated one month prior to death.

Complete examination was not possible because specimen was to be saved.

Body had a pigeon-breast deformity, bones quite soft. Important pathological observation in addition was that there was a choking of the duodenum and bile duct, extending into the intrahepatic ampullary dilatation, with several quite long cestodes. The same parasites are found in the small intestine. A striking feature is that the worms have dilated the opening of the bile duct into the duodenum so that the lumen at this aperture is almost equal to that of the duodenum at that point. The worms extend for a short distance along the tributary bile ducts but they do not penetrate the hepatic substance; there is no gall bladder but the dilatation of the

common duct is as great in size as a gall bladder could be for this animal. The mucosa of the first part of the small intestine shows congestion of only the tips of the rugæ. The heads of some of the cestodes are lightly attached to the mucosa.

Examination of the preserved specimen confirms the notes in so far as the parasitic condition of the bile ducts are concerned. The liver is a smooth, homogeneous, multilobulated organ, its sections being somewhat leaf-like as they lie over one another. The position of the two colonic ceca is right postero-lateral to the cecum and main mass of the small intestine. The ceca are 11 cm. long and, in the preserved state, about 3 cm. wide and take origin 40 cm. from the anus.

The diagnosis on this animal was somewhat limited because of the nature of the autopsy, but it is significant—osteomalacia—cestodes obstructing the biliary tract.

P. capensis ♂, 3147. 11–28–12—2–24–14. Adult.

This animal has been kept in an indoor cage where apparently it was in good condition until 3 days before death when he exhibited behavior indicating (to the keeper) that he was stiff and sore; he ate well nevertheless.

An acute catarrhal enteritis existed, there were also some indications of a low grade chronic condition in the cecum proper. It was noteworthy that the stomach and true cecum were packed with dry crumbling food. It is noteworthy too that parasites were not found despite search, and the skeleton was not mentioned.

The kidneys although not grossly abnormal showed a low grade of acute glomerulo-nephritis. The liver showed hemosiderin pigmentation with hydropic degeneration of the cells.

P. capensis ♀, 3283. 11–28–12—8–3–14. Adult.

Appearance indicated approaching parturition and three days before death gave birth (with the assistance of head keeper) to a dead young one.

The organs of this animal except as noted below are entirely negative. Furthermore nothing exists that would seem to explain the failure to deliver herself of a second fetus. There is an apparently fully developed fetus in the R. uterine cornu, with its head just above the pelvic inlet. The L. cornu is large and boggy. The muscle of the right side is so thin as to be almost transparent.

P. capensis ♂, 4208. 6–1–16—2–14–17. Adult.

No history of abnormalities.

The general condition of the animal was good. The bones were within normal limits.

The stomach was distended by soft pulpy food. The squamous portion of the cardiac part of the stomach, extending from the junction, with the pyloric part, shows a triangular area on the lesser curvature beset with closely placed pointed, dead white, tough elevations. On section they were homogeneous. On the anterior wall of the fundus there were three superficial ulcers 2–4 mm. in diameter.

The intestine was practically normal. The common bile duct was distended by several cestodes extending into the intra-hepatic part.

The pia-arachnoid contains about an ounce of free blood about the base of the brain. There was found no rupture of vessels or fracture.

Examination of the preserved specimen of liver shows the usual lobulations and the dilated gall duct. The organ is not cut but surface shows a slight papillary condition that suggests a bulging of the contents of the lobules.

A section from the junction of the squamous cell portion and the glandular part shows an abrupt change from true long cellular tubular glands to blunt extensions of squamous cells approximating a gastric glandular arrangement. This gives way gradually to a stratified squamous epithelium. Both layers seem unusually packed with epithelial cells and there is some depolarization of nuclei especially in the more cellular portions. It gives a strong suggestion, from the multiplicity of cells and irregularity of membrane, especially the thickness of the horny layer, of a papillary tumor.

P. capensis ♂, 4658. 6–20–14—2–5–17. Adult. 4 lbs.

The notes of this animal indicate a gradual decline for a year before death.

The general condition of the body at autopsy was not far from normal.

The papillary ridge that separates the esophageal from the pyloric portions of the stomach, showed at one place a marked increase from normal size and there was an excavated ulcer in the center. There was in addition a slight irregularity of the mucosa suggesting gastritis. A very slight increase of the fibrous tissue in the liver also existed.

The bones are not noted as incorrect and it would seem that the nutrition of the animal had been good.

The condition of the stomach was diagnosed at autopsy as epi-

thelioma with ulceration. Inspection of the histological preparation shows it to be a progressive acute ulcer with really enormous hyperplasia of the papillary elevations of the cardiac portion.

P. capensis ♀, 4982. 7–19–18—12–3–18. Adult. 3⅛ lbs.

This has a history of poor condition, during the five months it was here, never having thrived, and that the fore feet had been frozen. There were ulcers on the heals of the hind feet.

The skeleton is markedly deformed from an osteomalacic softening which had partly healed except at the epiphyseal ends where they were enlarged and nodular. The chest is of the pigeon-shaped type.

There was a slight thickening of the colonic mucosa giving the suggestion of an infiltrative colitis. No tissues were saved.

P. capensis ♀, 5123. 7–19–17—5–16–19. Adult. 4 lbs.

History is indefinite and states only that it seemed to be paralyzed seven weeks before death. It certainly did not move about for its coat was smeared with discharges and the hairs falling out.

There were osteomalacic irregularities of the long bones, ribs and vertebræ.

There was marked edema of the intra-laryngeal tissue, the lumen of the larynx being almost closed. There was a thin fluid and considerable currant jelly clot in both pleural sacs. The lungs were slightly compressed and in certain places atelectatic. A clot similar to the above lay between the liver and diaphragm. The other organs did not show any marked pecularities.

There were several ulcers in the cardiac portion of the stomach, one involving the papillary segment at the top of the pylorus. There is a slight follicular hyperplasia of the entire small intestine. No tissues were saved.

P. capensis ♀, 6100. 3–2–21—3–18–21. Adult.

Received in bad condition. Animal was not healthy and seemed to have a secondary anemia. There were small cestodes crowded into the distended gall duct. There were cestodes in the colon.

The junction of the esophageal and cardiac portion of the stomach shows an external longitudinal and internal trasverse or diagonal musculature which passes inward with occasional strands of definite muscle. There is no well ordered and clearly outlined muscularis mucosa. The submucous layer is an intricately layered strand of fibrous tissue. The basal cells of the epiderm are closely placed but appear definitely separated, cuboidal or polygonal ele-

ments with nearly round nuclei that tend to be arranged at right angles with their base. This layer of cells rapidly turns into regularly arranged squamous cells near the surface. This external layer is definitely acidophilic. The larger cells contain easily recognizable granules.

Note.—At one place in this membrane there has been an acute purulent and ulcerative inflammation that has wiped away the true squamous covering and left the normal digitations somewhat distorted.

Second Note.—There are certain cross sections of these irregularities of the epidermal lining that give so strong a suggestion of epithelioma or even carcinoma that the similarity cannot be ignored.

The junction of the cardiac and fundal portion. There is a wide distinct longitudinal muscle with a diagonal external subperitoneal layer. The internal layer which merges with the submucosa is largely longitudinal, but oblique in its relation to the other layers. The submucosa is very tightly wound and the fibrous tissue sturdy in its construction. The compound tubules of the mucosa are delicate. The cells are mostly chief cells with a moderate number of small acid cells, which have a granular eosinophilic cytoplasm. The change from this glandular zone to the stratified squamous zone is abrupt. At first there is a tubular gland-like arrangement of the squamous cells but later this gives way to a blunt extension of the lining toward the musculature. The entire layer is comparable to that described for the esophageal part although somewhat thinner.

Another section running from the mid-pyloric region to a position beyond the opening of the bile and pancreatic ducts. The gastric region proper shows a slight distortion of the mucosa, partly by congestion, partly by emptiness of the cells and partly by fibrous tissue. This is a low grade chronic gastritis. In the pyloric and upper duodenal region there is considerable pigmentation near the tips of the villi. The glands of Lieberkuhn are empty. There does not seem to be any infiltrate of inflammatory character. There is perhaps one small erosion. The ampulla where the biliary and pancreatic ducts empty is lined with a columnar epithelium over a thin mucosa of irregular tubular glands over a thin zone of racemose glands of varying thickness.

P. capensis ♀, 6121. 3–2–21—4–3–21. Adult.

This animal simply gave a history of weakness a day before death. It evidently had diarrhea judging by condition at autopsy.

The biliary tract is free of worms, but a small number were

found in the colon. It is noteworthy that there was a brown red pigmentation of the villous tips in the small intestine.

P. capensis ♀, 6127. 3–2–21—4–9–21. Adult.

This animal had not done well and showed loose discharges. It was a poor thin specimen with dry hair and skin.

There is a slight inflammation of the larynx and trachea. A pneumosyssus (sp. foxi ?) was found in the tracheal mucus. The lungs were apparently not involved. The origin of the arachnid is not understood.

The smoothness and homogeneity of the liver is noted in the records of this case. Dark pigmentation of the tips of the villi are noted in the duodenum. This fades as one goes toward the ileum.

P. capensis ♂, 6353. 3–2–21—8–7–21. Adult.

The history of this animal is entirely negative. Its condition was good at autopsy with the possible exception of some flabbiness of the muscles and fatty infiltration of the liver.

P. capensis ♂, 6359. 9–3–20—8–9–21.

No history of this small or young or runt-like animal. Nutrition was not good. There was suggestion of fibrosis in the liver which unfortunately was not preserved for microscopy. There is a slight enteritis with some early ulcers, probably lymphatic in origin. The kidneys suggested parenchymatous degeneration which was confirmed by microscopy. The bones seem to have been within normal limits.

P. capensis ♂, 6746. 5–26–22—7–14–22. Adult.

Despite apparent generally good condition the animal refused to eat for two days before death, which was not easily explained by autopsy.

There were multiple small hemorrhages in the lungs. The kidneys showed marked swelling and opacity of the secreting portions; this was found to be an acute diffuse nephritis, confirmed by microscopy. The liver and bones were within normal limits.

P. capensis ♀, 7003. 5–26–22—2–15–23. Adult.

Had not been well for several weeks before death and for some days had had discharge from the nose. No adequate reason was found for this discharge.

The only organic findings concerned the liver and intestines. The pale yellow brown liver attracted attention. This was due to excessive golden brown granular pigment in liver cells that were themselves not badly damaged. Many coarse granules were found around the bile ducts also. The gross appearance of the small and large intestines suggested acute inflammation, but on microscopy this was not found. The general construction of the wall would perhaps be considered normal were it not for the presence of much dark brown pigment, in granules and in coarse masses, lying in the stalk of the villus, sometimes there being no other visible tissue at that place. There was no richness of cells and the epithelium was within normal limits. This unusual and excessive pigmentation could give rise to the suggestion of inflammation, but whence it came is difficult to decide.

P. capensis ♀, 7873. 3-4-24—5-6-25. Adult.

No history. The animal was in poor condition at autopsy, there being practically no fat. There was chronic inflamation around the border of the liver with a mass of adhesions between the gall duct and the peritoneum within which lies a number of cestodes. The worms had come from a distended bile duct that had ruptured. They were also present in the duodenum. The worms were determined by W. P. N. Canavan as *Zschokeella gan-biana* Beddard 1922. The liver is slightly enlarged, firm, mottled red and yellow. Under the microscope there is not a great deal of cellular change, but there is a large amount of golden yellow pigment in Kuppfer cells and free around the bile ducts.

P. capensis ♂, 8848. 3-4-24—9-17-27. Adult.

No history.

The thyroids showed a slight enlargement which shows under the microscope an irregular hyperplasia, some of it in adenomatoid arrangement with colloid. The parathyroid showed hyperplasia.

There was a pleuritis and lobar pneumonia due to the Fried-lander bacillus. The major portion of the pneumonia was on the right side. It was in a mixed stage of red and gray hepatization. The pericardium shows a very early pericarditis.

Below the diaphragm the organs are decomposed, but a careful search failed to reveal hepatic cestodes known to occur in these animals.

The bones were within normal limits. It is worthy of remark that this specimen, the longest in captivity of our records, failed to show degenerative bone disease. There is no known difference in

diet for the period of his life, and it overlapped the life periods of others that lived but a short time.

P. capensis ♂, 10,056. 7–30–29—3–20–31. Adult.

No history. The animal was in poor condition at autopsy and the skin, fur, fat and muscles all suggested inanition.

The lungs were collapsed as in a slow death. The thyroid was slightly enlarged and showed under the microscope a hyperplasia without colloid. The liver is negative grossly but shows under magnification a coarse green-yellow pigment in the liver cells.

The bile duct is markedly increased in size due to several tape worms. The stomach is negative but the duodenum is thickened and intensely congested. The lumen contains blood; its source is not evident. This duodenal wall shows an acute and hemorrhagic catarrhal enteritis. The spleen is negative grossly but shows slight atrophy under the microscope.

The ribs show multiple periosteal thickenings and healed fractures that distort the outlines of the thorax. The sternum is bent like an S. The shafts of the long bones are thin and fragile.

The following two cases are well recorded and illustrate the conditions found when osteomalacia exists. For record they are repeated almost entirely as the protocol was made at time of death.

P. capensis ♂, 10,263. 4–3–31—11–14–31. Adult.

No history. The general condition is poor. The coat is short and rough, the skin is dry and scaly. The muscles are pale and flabby, and fat is not seen. The bones are soft, the shafts of the long bones seem to be reduced in thickness and cut easily with a knife. The marrow is soft and bright red in color. The ribs are especially soft and distorted and have numerous fusiform pale gray thickenings along their lengths. The sternum is S shaped and the whole thorax so deformed that respiration must have been considerably embarrassed.

The mouth, teeth, pharynx and esophagus are negative.

The internal organs particularly the heart, liver and spleen are reduced in size, soft and pale. The thyroids are enlarged, pale gray and firm. The stomach is empty and the cardiac portion presents the usual appearance for this animal except there appear to be numerous small erosions between the elevations of the mucosa. The small intestine is dilated and the walls are atonic. The large intestine is negative. Death is apparently due to malnutrition.

Histological Notes:

Liver. Capsule and stroma are negative. The central veins and adjacent capillaries are widened and liver cells in this region are shrunken, indistinctly outlined and pigmented. Many nuclei are pynknotic. Passive congestion and pigmentation.

Bone Marrow. Fat is reduced to a considerable degree and there is definite hyperplasia particularly involving the red cell forming elements. Blast cells of both types are very numerous and are seen in the central vein of the marrow. Lymph nodes are also present in this section. Hyperplasia.

Thyroid. The gland is made up of chiefly small acini lined by irregular columnar cells. In many areas there seems to be definite multiplication of acini. All of those of any size contain colloid. Hyperplasia with colloid.

Spleen. Trabeculæ and capsule are negative. Follicles are small and inactive. The pulp is poor in cells, but all spaces are extended with blood and numerous pigmented monocytes are seen. Congestion, pigmentation and atrophy.

Heart. Epicardium and endocardium are negative. Muscle fibers are indistinctly outlined, swollen and granular. Nuclei vary greatly in size and staining character. Striations are faded in many fibers. Myocardial degeneration.

Kidney. Blood vessels, stroma and glomeruli are negative. Epithelium is swollen, granular and vacuolated, and nuclei are faded in a number of cells. Cloudy swelling.

Femur. The cortex is widened and irregular. The periosteum is thickened and edematous. Blood vessels are increased. Osteocytes lie in large spaces. Numerous small erosions into the cortex and the increase of thickness seem due to the formation of osteoid tissue. The network of osteoid tissue fills the marrow cavity near the epiphysis and the zone of calcification is wide and irregular. The articular surface is thickened by fibrous tissue. Marrow in this bone is hyperplastic. Osteomalacia.

Rib. Changes are slightly more advanced than in the femur, the marrow being replaced by loose fibrous tissue rich in blood vessels. Osteomalacia.

P. capensis ♀, 10,337. 4-3-31—2-19-32. Adult.

No history. The general condition is poor. The coat is complete, muscles are thin and pale. Fat is not seen.

The thyroids are considerably enlarged, firm and pale gray. The trachea is negative. The lungs are collapsed and dull red brown in color and moist on section. The heart is flabby, pale,

otherwise negative. Vessels and aorta are within normal limits. The liver is entirely negative. The gall bladder is absent, and there are no parasites seen in the duct. The spleen is soft, dull red brown in color and follicles are not visible. The kidneys and adrenals seem within normal limits.

The mouth and teeth are negative. The esophagus and stomach are empty, the latter showing the usual subdivisions with thickened mucosa in the upper portion. The intestinal tract seems within normal limits throughout. The pancreas is negative.

The sternum and ribs are considerably misshapened, the former being bent in a S shape. The ribs are quite elastic and soft with numerous fusiform periosteal thickenings. These bones cut with very little resistance. The long bones of the skeleton are soft but do not break with ease.

Death in this animal is probably due to malnutrition.

Histological Notes:

Liver. Blood vessels, particularly the central veins and adjacent capillaries, are distended. The liver cords are shrunken and the liver cells are diffusely pigmented. Kuppfer cells also contain masses of pigment. Passive congestion and pigmentation.

Thyroid. The gland is made up of relatively large acini in which there is duplication and reduplication of the lining epithelium until many small ones are formed. Practically no acini contain colloid. Hyperplasia without colloid.

Lung. The tissue is collapsed, the alveoli contain hyaline coagulum and numerous pigmented monocytes. One part of the tissue shows dense infiltration by polynuclear cells and the bronchioles in this area contain exudate. Chronic passive congestion and bronchopneumonia.

Kidney. Blood vessels, stroma and glomeruli are negative. Tubular epithelium is swollen and granular. Nuclei stain dully. Couldy swelling.

Heart. Blood vessels and stroma are negative. Muscle fibers everywhere show swelling, enlarged irregular nuclei and loss of striations. Myocardial degeneration.

Intestine. The serosa is elevated, apparently by fluid. Muscular coats seem well preserved. Mucosa is infiltrated by lymphocytes and pigmented monocytes. Tubular structures show considerable irregularity. Chronic catarrhal enteritis.

Spleen. Capsule and trabeculæ are negative. Follicles are present only as small collections of lymphocytes about large germ centers, many of which contain hyaline scars. The pulp is densely congested. Passive congestion and atrophy.

Rib. Section shows a thickened cellular irregular periosteum which is eroding and extending into the bone in numerous areas. Osteocytes are numerous and lie in large spaces. Vascularity is greatly increased and blood vessels are surrounded by active fibrous tissue. Osteoid tissue is encroaching on the old bone and filling the cavity. Osteoclasts are numerous in several areas. Osteomalacia.

The last two cases illustrate what must be designated as pathological abnormalities, no single one of which, perhaps, would lead to the death of the animal. The hepatic, thyroidal, splenic, renal and intestinal conditions are usual when degenerative bone disease exists and help to make up the total picture of avitaminosis that is distinguished by faulty skeletal structure. It will be recalled that in some of the former ones evidences of weakness, laming, or even paralysis have been observed; this would also go along with avitaminosis. Unfortunately we do not have brain, nerve or weight studies on these animals; this can remain for a subsequent study. In none of the animals was there evidence of the degeneration of the cornea to be expected with the loss of vitamin A. No data can be given on the deficiency of growth and reproduction vitamins, since the animals were not weighed and only one is recorded as pregnant.

An analysis of the records just cited as the experience of our collection in the maintenance and exhibition of the hyrax affords a few interesting and profitable observations.

During the records of the Laboratory there have been 19 specimens, 9 males and 10 females. The average exhibition period for the total has been 12.2 months; for the males 15.8 months, the females 9.0 months. The limits of exhibition time have been one half month to 42 months. The expected longevity of the males is evidently longer.

The following is a full copy of the notes of S. S. Flower (Proc. Z. Soc. London 1931, 197.) The figures quoted by him are considerably in excess of those we are able to report, including also the maximum captivity period.

The maximum recorded length of life for a Hyrax in the London Zoölogical Garden is that of a female Cape Hyrax, *Procavia capensis* 2–6–1911—22–8–1917, 6 years, 2 months, 20 days.

In the Giza Zoölogical Garden the Cirogrille, or Wabur, *Procavia syriaca*, lived better than Hyrax brought from South Africa or caught in eastern Egypt; but still although they appeared to flourish and bred freely (even to the third generation) they never lived long. The average of the ten individuals that lived longest was only 4 years 11 months 21 days. A male lived longest, born 15–3–1916, died 6–8–1923, 7 years 4 months 21 days. The record for a female, born 27–3–1917, died 13–8–1923, was 6 years 4 months 16 days.

The condition of the specimens during captivity has been good in only a few cases, whereas it has been the common story that they drooped more and more and did not thrive. The causes of death have been varied, the most conspicuous of which being bone disease, gastritis and heavy infestation with parasites, all of which subjects are dilated upon in later paragraphs.

The exhibition enclosure has been large enough but mostly within doors. The animals were not kept where they could be frightened by neighbors. A place to hide in a hurry is always demanded. The diet has been bread, lettuce, apples, carrots, sweet potatoes, rolled oats and cracked corn, bananas and fresh grass. It is in this mixture that perhaps their malnutrition is based. Bigalke at Pretoria, Transvaal, writes to the author that hyraces are fed in the afternoon on fresh lucerne and wheat bran.

Osteomalacic deformities have been frequent during life, and weaknesses, that may have been the result of inadequate vitamin supply, are recorded. Four have shown such weakness and seven have shown advanced skeletal changes of the osteomalacic type. The principal findings after death of these animals have been both bone removal and incomplete fibrous osseoid regeneration. The parts most frequently attacked were the thorax and long bones; the skull, maxillæ, pelvis and terminal parts of extremities were less affected. This process seems never to have healed completely although in one case some evidences of recession were observed. There were no

cases of hypertrophic or deforming type sometimes encountered in ungulates. The most pronounced cases are associated with thyroid gland hyperplasia. Disease of the lungs and of the intestines proper, often seen in association with bone disease, were apparently of no great moment.

Certain anatomical features are definitely associated with the peculiar pathological changes that occur in these animals but there are in addition morphological characters of considerable interest distinctive of them. The construction of the teeth and the nature of the gastrointestinal tract may have a distinct place in the use of food and the diseases of the bones.

The teeth are designed for gnawing and for grinding, which function is indicated by the shape of the incisors and molars. Further support for the principle that hyraces should have and are prepared for bulky food that requires comminution and softening is found in the capacity and lining of the rumen-like left cardiac portion of the stomach. A small portion of soft food could be used but twigs or even sticks, leaves, bark, fibers, beet tops and more corn-like particles are needed. Prunes, figs, rutabagas might be added. Bread, apple, sweet potatoes and bananas, which form mushy matter in the stomach, are contraindicated. A readily available inorganic diet is apparently needed, probably aided by such sunlight as they will use. In the absence of the latter, artificial sunlight or small quantities of irradiated cod liver oil seem demanded because of the susceptibility of their skeleton.

The best notes upon the microanatomy of the hyrax are to be found in Oppel, Lehrbuch der Vergleichenden Mikroskopischen Anatomie der Wirbeltiere, 1897. This author quotes, and adds little to the studies of Owen, Flower and George. From the notes in sections on the esophagus, stomach and intestines (Parts I and II) the following may be condensed.

Oppel quotes Owen and Flower as stating that the first and left two thirds of the stomach is covered with esophageal epithelium. (According to our observations this would depend upon the dilatation of the organ. This left chamber, which is probably masticatory

and not digestive, seems more distensible than the small right side, which grossly and microscopically has a more sturdy musculature. Ed.) The division of the stomach into the predominating cardia and minor pyloric part is recognized by all observers.

Oppel observes that the musculature of the cardiac portion may be six times as strong as that of the glandular portion. While this may be true the distensibility of this seems to be very great while the pyloric muscles seem to be more limited in action. He states that the muscle of the pyloric part may be only .1 mm. (This is not the case in at least two of our specimens in which it exceeded 1 mm. Ed.)

There may be mucous glands in the esophagus proper, with two or three divisions.

The biliary and pancreatic opening are together about one inch below the pyloric ring; only one pyloric opening is known. A few small lymph nodes may be detected by transmitted light, scattered through the small intestine and one agminated nodule near the large intestine.

The peculiar anatomy of the stomach deserves still further description. The left part is distended, suggestive of the rumen of herbivores, and covered by a tougher covering, an extension of the inner esophageal tunic. This is composed of squamous cells, stratified and arranged in a papillary manner, the whole giving the impression, to the eye and the palpating fingers, of the skin. This portion of the stomach is ended and clearly separated from the digestive part by a papillary ridge that runs from near the cardia to the greater curvature. Under magnification the chitinous or keratinized innermost layer is quite similar in all, except that in case of active inflammation it is thicker, looser and softer. However the deeper generative layer of basal cells may be several cells deep, extending as irregular digitations into the submucosa in a manner sharply suggesting carcinoma of the basal or late squamous type. (Fig. 1.) No true limiting or so-called basement membrane can be detected. A fully formed, spreading ulcerating, metastasizing carcinoma has not been found. I blush to admit that when seeing this for the first time I called it a cancer. When one views the papillary ridge that separates the two parts of the stomach, the similarity is

great and a diagnosis seems warranted, but later the peculiar normal histological structure is found. However it is a peculiar normal construction. (Fig. 2.)

The squamous portion of the stomach and the papillary ridge at its end are prone to small ragged ulcerations, from

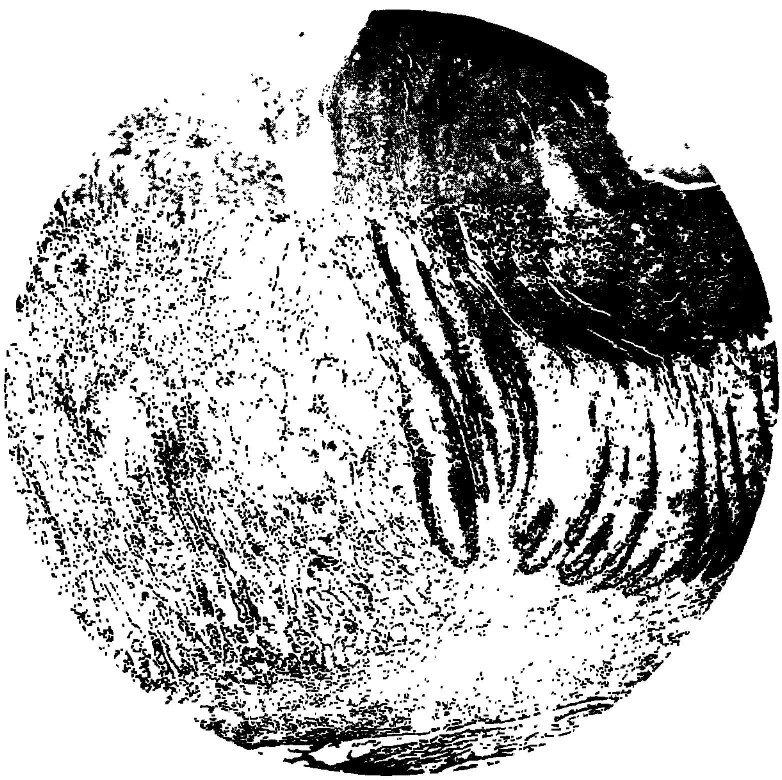


FIG. 1.

1 to 10 mm., that do not seem to lead to bleeding. Under the microscope they extend through the whole mucosa and destroy both the inner scales and the deeper basal layer. The defective area is filled with polynuclear cells and debris. The ulcers do not perforate. No cause is known; no special bacteria, worms or protozoa are recognized in the ulcers.

The most striking finding in the internal organs of our cases concerns the presence of large numbers of cestodes in the bile duct. (Fig. 3.) These have also been found in the duodenum and on two occasions lower in the gut. Six of our 19 specimens have been so affected. The only determination

FIG. 2.

we have of the parasite is that it is Zschokeella gambiana, Beddard. It has appeared in animals living here from one to twenty months; it is therefore imported and probably contracted in their natural habitat.

This parasite evidently lives in the upper small intestine by choice but finds it easy to enter the bile duct, dilating the

FIG. 3.—Liver, bile duct, pylorus and duodenum of hyrax showing bile duct enormously dilated with cestodes, opened from the rear. *a*. Liver. *b*. Ampullary widening of bile duct just within the liver. *c*. Widely distended bile duct. *d*. Irregular cutting of dilated bile duct. This is cut from over the worms and turned out. *e*. Pyloric end of stomach. *f*. Duodenum.

orifice in the duodenum, swelling out the bile duct till it may reach the diameter of an inch (normally about 2 mm.), penetrate the intrahepatic ampulla at the end of the duct and even extend into the beginnings of the intrahepatic ducts that are tributary to the main channel. Eighteen worms were counted in one case. Once the bile duct had ruptured, causing a local peritonitis that had produced fibrous tissue adhesions enclosing the worms. These parasites seem not to go into the liver tissue.

The cause of death in these cases is anemia, degeneration of the liver and malnutrition. They are not associated with bone disease specifically and indeed appear to occur chiefly in its absence. Do the worms leave when the nutrition is such that it leads to skeletal degeneration?

The hyoid bone has been noted as having a peculiar construction, a judgment amply supported by the accompanying drawing. (Fig. 4.) This scoop-like structure lies upon the

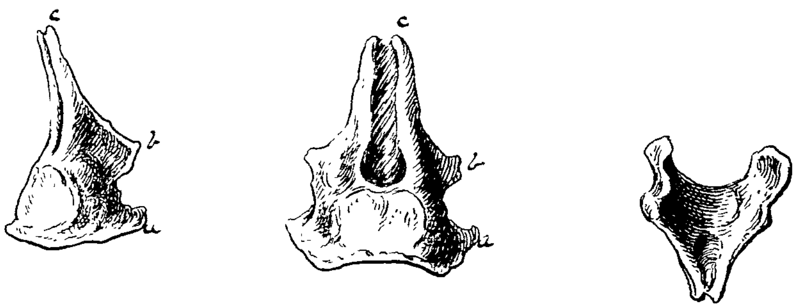


Fig. 4.—The hyoid bone of the *Hyrax capensis*, lateral, front and rear view, the last illustrating the scoop-like construction.

upper two thirds of the thyroid cartilage, to which it is attached by delicate ligamentous sheets. It is overlaid laterally by a thyroglossal muscle. Tapering superior processes extend upward to the base of the tongue, into the root of which they penetrate deeply. The close relations to the laryngeal cartilage and to the tongue seem to be its principal anatomical bearings. The lower posterolateral angle (*a*) forms one of the insertions of the constrictor pharyngis. The small extension

angle (*b*) about 1 cm. above this point and on the superolateral edge seems to form the origin of a strand of the hyoglossal muscle. A longer basis for this hyoglossal tissue is however the salient (*c*) formed by the upper end of the whole bone, that which was described above as running into the tongue. The body of the bone cannot be separated at the midline although there is a suggestion of fused ossification that must take place from the bilateral genesis of the branchial arches.

Each side has a lateral wing that bends backward around the thyroid cartilage to form the scoop shape. A sharp extension upward, the above noted processes, is found on each side (*c*) and these two points are joined by a thin but firm and translucent ligamentous tissue. The entire bone measures about 1 mm. at its thickest part around the inferior border, while the upper parts go almost to paper thinness. At the middle there is a very sheer layer with bone salts in it. The height of the bone is 2 cm., the width 1.7 cm. and the depth of the concavity is 1.2 cm.

These notes upon the hyrax are intended to illustrate some of the peculiarities of the animal's nature, anatomy and pathology. While far from a fully comprehensive analysis of the animal, they permit the drawing of certain lessons.

The life in captivity seems not to extend long beyond seven years. Information upon natural life possibilities is no greater for them than for other animals. But it is odd that their nearest zoölogical relatives, the rhinoceros and the elephant may live thirty to sixty years, while an exhibition of these two species lasting twenty-five years is not unusual. Even the horse, another variety with certain similarities, may live thirty years. The rodents, to which they have certain strong resemblances, live however only up to twelve or fifteen years and it may be that in the matter of longevity the otherwise far-separated Procaviidæ and Leporidæ approached each other.

This thought finds a little support in the dental supply of the anterior maxillary parts and in the habits of gnawing

vegetation. The dietary preferences of the two are certainly close. Gastric and skeletal diseases are not common to the two and the rabbit has no cardiac anatomy nor biliary arrangement of the hyracoidal form.

The anatomy of the stomach strongly supports the dental construction as an indication that fibrous vegetable matter and coarse corn-like food are suited as nutriment for this animal.

The peculiar construction of the first stomach and the liability to ulceration are noted. There is a suggestion, but no strong indication, that incorrect diet assists the development of the latter.

The skeleton of the hyrax is quite prone to osteomalacic weakening. This appears to be partly due to inappropiate diet but perhaps also to some extent that they do not eat so much as they should. This in turn may be due to the fact that they are not fed during the night or early morning, which is their habit. The diet should consist of coarse vegetable matter, especially twigs and leaves, omitting mushy substances.

The bile tract is often clogged with tapeworms that pass into it from the duodenum. These worms are probably acquired in the natural habitat of the hyrax. The peculiar hyoid bone has been illustrated.

RECENT DEVELOPMENT OF GEOLOGY AS AN APPLIED SCIENCE

CHARLES P. BERKEY

(*Read April 22, 1932*)

Ever since the time of William Smith, the English engineer, who found, over a century ago, that knowledge of the strata of England was useful to him in his engineering projects, the possibilities of the science of geology in this field of applied science has been recognized. Considering its favorable and early beginning, however, real progress in the application of geologic principles and data to practical problems of any sort was slow and halting. There was little call from the field of practise and little interest from the field of pure science. Like all true pioneers, William Smith seems to have been, in this respect at least, far ahead of his time.

Before his time much too great allowance seems to have been made for the supernatural. Unusual or exceptional phenomena were credited to the operation of processes assumed to be different from those operating now. Geologic processes were believed to be more or less catastrophic, with geologic history largely a series of revolutions.

Such principles would be difficult to apply. Without confidence in the orderly sequence of events and faith in cause and effect, giving a background of reasonably reliable explanation for most of the ordinary features and phenomena, practical service of the type rendered in late years to applied science would be impossible. The most acceptable doctrine assumes that the agents and processes now operating are the same as always have been and that the effects and products of former times were of the same nature as those resulting now.

Under this so-called "uniformitarian principle", the whole geologic field has been opened to interpretation on rather definite and simple rules. In this view, the formative proc-

esses still continue and the Earth is still developing. The various natural structures, products, behaviors, and conditions invite explanation. They have not simply happened, but have been made in an orderly manner and are to be accounted for in accordance with known laws.

Geology has always claimed a wide range of interests and relations. It had its origin in the realm of Astronomy from which field came explanations of earth origin and primeval history. The orderly succession of organisms of greater and greater complexity, represented in the fossil content of the stratigraphic succession, forms a major support for the principle of organic evolution in Biology. Pre-historic Archæology would lose much of its historical significance without the help that comes from interpretation of the geologic setting of its finds or stations. Some of these interests lead into fields quite foreign to the science of geology itself and serve to keep the science broad in its outlook.

Geology has exerted a profound influence on the every-day thinking and expressions of our time—much more than is usually appreciated. We should now feel quite lost without the ideas that center around the fundamental principle of orderly development under natural laws. This principle applies quite as well to the rock formations and surface features of the Earth as to its organisms. We have become accustomed to explanations involving consideration of enormous lapses of time, and extremely slow-working agents and processes, together accomplishing stupendous results. It is now a common thing to hear people who would not have admitted a few years ago that the Earth itself was so old, discuss the antiquity of a new fossil find in terms of millions of years. We have come to feel a certain satisfaction in the ideas that center around the antiquity of man and the evolution of organisms through a long sequence of increasingly complex organic forms. We have become accustomed to think even of our scenery in terms of orderly development through a series of stages of very different features.

One of the important trends of geology during recent years

has been the tendency to quantitative treatment. This science does not lend itself very readily to exact measurement, but that is the direction of development in all sciences as they reach maturity. So it is with geology. The elementary stages have been passed and the greater accuracy that belongs to measurement and computation and analysis is the present vogue. This change requires greater precision of statement, and greater caution than is to be found in earlier work. The science is much less speculative than formerly although not less imaginative. It distinguishes with greater care between the inferred and the proven, and between a working hypothesis and the final, well-supported conclusion. The applied science demand is to know what, and where, and how much. Many geologic phenomena formerly stated in general terms are capable of measurement and other definite determination, and it is now appreciated that they are more useful in this new form. With this change the geologist becomes more dependable, and his contribution has come within the range demanded of the applied sciences.

In the early days the science gained much from the fields of mining and civil engineering, and these sources are still searched eagerly for their contributions, but in recent years geology has returned full measure to them in service. It is to the credit of present-day geology that it has been found possible to "reverse the reaction" and contribute materially to the success of engineering projects.

There are at the present time whole fields of practical geologic activity that were entirely unknown or in which there was no demand at all twenty-five or thirty years ago. More geologists, for example, have been actively engaged in work with the petroleum industry in the last few years than there were in all other forms of geologic service put together twenty-five or thirty years ago. This industry has used expert stratigraphers, micro-paleontologists, petrographers and geophysicists in the most spectacular assault on hidden mineral wealth that the world has ever known. And their success has

been so great that it has almost ruined both the industry and their own professional calling.

More advisory service is rendered in a single week in connection with projects in the field of civil engineering than was called for a generation ago in a whole year. The structural geologist has a place at the consultants' table with the engineer. The application of geology has increased in other directions, especially in mining, where the geological staff takes prominent rank in the operating division of nearly all large companies.

The practical professional geologist therefore finds a great range of possible activity. Questions and problems are brought to him, not only from every region on the face of the Earth, but from its multitudinous practical interests. Many come from the average non-professional person. These are mostly identification questions, including possible value, classification of rocks, fossils, minerals, and ores, as well as explanation of common physical features or phenomena.

Others come from the mining industry and from engineers using or depending on natural resources. Their questions usually relate to sources of new supply, differences in quality, questions of origin, principles governing distribution, or occurrence, special content, or possible changes of value with depth.

Yet another class of problems comes from the civil engineering profession. They usually involve interpretation of rock floor conditions, depth and quality of overburden, strength and stability of foundation, local structural conditions requiring special attention, water circulation, permeability of overburden or rock floor, sources of structural material, possibility of destructive attack by natural agents, and the probable effect of the changes to be established by proposed construction. Some questions come from quite unusual and unexpected sources. Perhaps it is allowable to refer to several of the more unusual sort, simply to illustrate this point.

A Detective Service

In a shipment of crude rubber from the Amazon River, routed through the port of New York to an inland city, the consignees found that rocks had been substituted for a portion of the shipment. The transportation companies then undertook to find out where the fraud was committed so as to fix responsibility, and a geologist was consulted in the hope that identification of the "rocks" might fix the place. In short, it was a detective's job. The most promising opportunities would appear to be on the Amazon, where the shipment originated, or in New York, where the cargo was transshipped. This was rather easily solved, because the material substituted proved to be chiefly fragments of concrete in which typical "Cow Bay sand", a well-known local supply in the New York market, had been used. Further inquiry, following that observation, led to the discovery that repairs on a neighboring pier in New York Harbor had made large quantities of broken concrete of the same quality easily available. With this clue the responsibility was readily fixed.

Quality of a Substitute

Some years ago, one of the large pottery companies in New Jersey experienced a severe loss in burning a run of wares. Investigation seemed to show that the kiln had been handled as usual and that there was only one difference in the material. They had recently bought a new lot of ground flint for use in the clay mixture. To all appearances it was the same as had been used before, but came from a new source and had not been put to the test of burning.

Now it should be noted that the silica flour used for such purposes seems to be a very critical substance. By analysis it is essentially pure silica, but it is well known that ground quartz, which is also pure silica, will not give as satisfactory results for this purpose as ground flint. Since the difference is reflected in the structure, this can be detected by the petrographic microscope. The sample submitted for test, however, was already ground to microscopic fineness and the question

was whether such material could be successfully compared with the original standard stock of ground flint. This proved to be readily done, for the modern microscope allows critical determinative inspection of exceedingly fine particles. When this method was used it was found that the new material was much more crystalline than the original standard stock, a dominant proportion of it giving the test of crystallized quartz and proving that it was not the same quality as the microcrystalline, almost amorphous flint that had always been used.

A Condemnation Claim

An unusual problem developed when exploratory investigations for the Catskill Aqueduct were made along the proposed line across Foundry Brook Valley above the Village of Cold Spring in the Highlands of New York. One of the borings encountered an artesian flow of water. Little attention was paid to the matter at the time, but in due course, when it came to taking title to the land for actual construction, the City of New York faced a claim for extra value on account of the artesian well.

It was found then that in the meantime the owners of the land had exploited the water. Analysis showed it to be of excellent quality and the source, being unusual, gave it advertising value and character, and something of a market under the name of Mount Taurus Artesian Water. With this reputation the owner felt that he ought to be paid liberally for the loss of his well, despite the fact that it did not exist until the explorations of the City developed it. The question was a fair one, however. As the matter stood the well belonged to his property and, if the ground were taken, he could not enjoy its use. The land itself was of little value but it carried a claim of seventy-five thousand dollars for the well.

It was found on making a geologic inspection that the local conditions which made a flowing well from the crystalline rocks of the Highlands possible were very simple. A crush-zone in the rock floor, marking an old fault, parallels the side of the valley so that it may be followed from higher to

lower ground down stream through this property, crossing the tunnel line. This zone allows water to move in and along it from higher to lower ground in the normal manner. The rest of the floor is comparatively sound crystalline rock. The whole floor, with the crush zone through it, is covered with a heavy, tight mantle of glacial drift. On this account the water moving down through this crush-zone could not escape until the thick mantle was perforated by the boring, although water could enter along the mountain side farther up the valley at a higher level where the cover is not so heavy.

The boring had penetrated this tight cover into the water-bearing crush zone beneath, and since it was under head, there was an artesian flow. If this explanation is true, however, it would be possible to tap the same water at other places on the original property beyond the proposed taking lines. The conditions on the ground condemned were not unique and the particular spot where this boring was made was not the only possible one where a well could be developed. This line of defense helped materially in securing more reasonable terms.

A Complex Engineering Project

The tendency in recent years has been both to broaden the range of geologic service and to take it into more serious account. A noticeable change in this field is the recognition by engineers that geologic advice is essential to successful handling of projects having to do with the condition and behavior of the ground. Neglect of this requirement, where the natural physical features are treacherous and not well understood, has led to occasional failure and tragic consequences. The most important present-day contributions of geology in the engineering field is in the direction of more economical handling of construction and greater safety, through better understanding of the physical conditions.

It is a long step in advance to take the geologist into full account in the preliminary stages of reconnaissance and development of plans, as was done in the case of the Catskill Aqueduct for the City of New York. In that extensive and

costly project the whole plan was worked out in accord with the geologic findings. It is a good example of coordination of geologic investigation and engineering plan.

The Catskill Aqueduct was designed to bring water a hundred miles from the Catskill Mountains to New York City. It was appreciated in the beginning that the long list of engineering structures including dams, cut-and-cover aqueducts, with several grade and pressure tunnels, would encounter a great variety of geological conditions. More than 30 different rock formations would be penetrated by the 50 miles of tunnels. Every kind of overburden known in the region would be encountered. Every variety of physical condition and every kind of special rock structure would have to be considered in making plans and in constructing these works.

Furthermore, the geologic features and conditions were found to vary so much from one section of the work to another than the conclusions reached at one place could not be relied upon for the next one. In each case it was necessary to make special investigation in order to secure reliable and independent data so that plans could be adjusted to the special conditions to be met. This investigation was carried on systematically on every section of the project with the deliberate purpose of avoiding troublesome conditions, if they could be avoided, or by shift of site or line, and by modification of plan or method of construction, if the route could not be changed. It is evident, of course, that none of these decisions could be made without first developing a reliable practical understanding of the whole range of geological and other conditions.

It ought to be recalled in this connection that a much more common method among engineers in earlier time was to take the risks, or let the contractor take them, and discover the actual conditions during construction. Such methods almost always led to special claims by the contractor to cover excess costs or losses or delays, or other expensive requirements arising from the necessity of meeting conditions not anticipated when the contract was let. Under such circumstances it often happened that the final cost of a project amounted to

twice as much as the original estimate and sometimes the final costs have been three times as much as the contract price. Aside from the added cost, there have often been long delays and enforced change of plan after construction began, which greatly added to the confusion and reflected more or less on the reputation of those sponsoring and executing the work.

Undetermined geological conditions were the common source of these costly experiences, and in recognition of this fact the engineers in charge of this work for the City of New York decided to eliminate as much uncertainties of this type as possible. In accord with that decision arrangements were made for geologic studies on every major section of the project. Locations, designs, plans, estimates and contracts were made in keeping with the needs indicated by these and other studies.

The result was not only satisfactory from a progress standpoint, but established a record for avoidance of claims and excess costs that is looked upon as a standard accomplishment. The original estimated total was not overrun. Claims for extra cost to cover unforseen or misinterpreted geological conditions were singularly unsuccessful. It was clearly shown that in present day handling of large engineering projects the Science of Geology can render effective practical service, contributing not only to more accurately adjusted plans, but also to their economical execution.

One of the major sections of that project, the eighteen-mile City Tunnel No. 1, extending from the Yonkers line down through the heart of New York City to Brooklyn, serves to illustrate another special service brought into prominence by projects involving long tunnels. Of course, a line for such a tunnel could be drawn in the Engineer's office; a certain definite sum of money could be set aside for exploratory borings; these borings could be distributed with regular spacing along the line to determine the sub-structure; and then construction with its usual uncertainties could be undertaken. A much better method, however, was followed. Three alternative lines were drawn by the engineers. The geologist was directed to study and choose between them on geologic evidence, and

suggest changes, or even advise a new line if these were found to present very objectionable features. The study was made and modifications were suggested. This report was considered by the engineers who then offered a modification based chiefly on engineering and economic factors. In this form the case was returned to the geologist for detailed study and specific advice on amount and kind of exploratory investigation needed. When this study was finished only four comparatively short sections of the 18-mile tunnel were judged to be sufficiently uncertain to require detailed exploration, and work was begun at these places as the first actual step involving exploratory expense. All of this work from beginning to end was laid out and controlled on geologic data. The very first returns indicated that the spots selected deserved the additional study called for, and construction finally proved that the general interpretation was correct. The tunnel was successfully driven without discovering disturbing or discrediting conditions, and without a single claim based on misinterpretation. This case exhibits, better than any other within the writer's knowledge, the systematic use of geology in the inception of a large engineering project.

This work was done twenty-five years ago. Since that time geological advice in engineering work has steadily increased. Some of those engaged directly on the Catskill Aqueduct like to believe that the success of the service rendered there was in part responsible for the improved standing of applied geology in this generation. Be that as it may, certain calamitous happenings affecting work where geological precautions were not taken served to emphasize the question from another angle.

Public Safety

It is of prime importance to determine, before a structure is built, whether the ground on which it is to rest will furnish adequate support, or whether in case of doubt, it would be possible to improve the situation by a shift of location or a modification of design, or a change in method of construction.

Most of the tragic failures or so-called "accidents" connected with projects of an engineering character, in so far as they have to do with geologic features, could be fully guarded against by appropriate pre-construction studies. It is not unusual, of course, to be called in for advice after difficulties or dangers are discovered.

Cases primarily involving public safety have come into special prominence in the last few years. The most famous one was the St. Francis Dam near Los Angeles. This dam, holding the waters of a great reservoir, failed in 1928, resulting in the loss of four hundred lives by flood and the ruination of a whole valley. In this case a fine, well constructed, concrete dam was founded on an insecure foundation. Probably a safe dam could have been built if the physical conditions had been thoroughly investigated and taken into account in time to modify the design and plan of construction so as to meet the requirements.

This tragic failure brought into new prominence the question of public danger from these great engineering works, and so the importance of geologic advice and cooperation was again emphasized. The State of California passed legislation requiring the State Engineer to pass on the safety of all such structures in that state, and a Consulting Board on Safety was appointed.

Almost the first case brought to the State Engineer after this legislation became effective illustrates the importance attached to this question of safety. The first large case was that of a great dam at the Forks in San Gabriel Canyon, California, then already under construction. If it were to fail it would endanger half a million people living in the lower reaches of the valley and adjacent ground in the Los Angeles district. Recognition of the critical importance of geology in the problem then facing the responsible officers is indicated in the make-up of the Board. On this Board there were three engineers and three geologists.

In similar manner the City of Los Angeles, in the service of which the ill-fated St. Francis Dam was built, promptly ac-

cepted the verdict as to kind of responsibility and adopted a policy of consultation on new projects of this kind which is reflected in the make-up of its present consulting board, which has three engineers and two geologists.

It is at least encouraging to note that in most large undertakings now the geologist is given a reasonable opportunity to be of real service by helping develop the program. His advice is expected to enable the engineer to plan more wisely, to construct more safely, and to carry the project through with less interruption from unsuspected conditions and with greater economy of time and money. If the advice is sound, it ought to be possible to reduce post-construction claims for extra cost to almost the vanishing point. For if the geologist is competent in this field, he can point out the uncertainties of the physical situation and direct the exploratory program so as to determine the precise conditions to be met and thus either avoid the worst difficulties, or meet them squarely. He can forewarn the construction staff of questionable behavior. Most difficulties can be met readily and without great cost or danger if the need is foreseen.

Major Public Works

The development on the Colorado River, commonly known as the Boulder Dam project, illustrates the application of geological study and advice in connection with a government project of great magnitude. When this project had reached virtually an impasse in 1928, in the Congress, it was appreciated that little further could be done until the question of feasibility was settled. In that question there were two major elements: first, its physical feasibility, resting primarily on local geologic conditions, and second, its economic feasibility, measured by its prospective accomplishment and earnings.

Responsibility for making study of these problems and reporting to the Congress was placed on a Board of five, known as the Colorado River Board. It speaks well for the confidence that their report gave to recall that the report was accepted as evidence that the undertaking was feasible and

Congress thereafter, within two weeks, passed the necessary legislation.

It is also gratifying to recall that in this great controversial matter, finally recognized as dependent on the question of engineering feasibility, the Government of the United States recognized for the first time, I believe, the relative importance of applied geology by naming two of the five members of the Colorado River Board from the geological profession.

Probably the magnitude of modern engineering projects is responsible in part for the increased emphasis on this phase of applied geology. Major projects now undertaken introduce extraordinary conditions. Many structures are of enormous size. They demand great stability or soundness of foundation, or water tightness, or resistance to destructive attack. Any one of these items may be a vital factor in the success of a project. For example, the Hoover Dam on the Colorado River is to be 725 feet high. That is twice as high as any dam now in service except one just recently completed. It involves enormous weight and other unprecedented features. Such cases must depend on application of principles for there is no precedent.

Recent success in avoiding costly mistakes encourages continued use of geologic advice in many practical ways. It has been found to be an economical service and it appears that geology has made a permanent place for itself in the applied science field.

MAGNETIC DEFINITIONS FROM THE CIRCUITAL STANDPOINT

ARTHUR E. KENNELLY

(*Read April 22, 1933*)

Purpose

There have been many misunderstandings and differences of opinion among magneticians, during the last forty years, in all parts of the world, as is shown in the literature of both basic and applied magnetism. Competent writers differ, for example, over the definition of so fundamental a term as "magnetic field." Yet there is no dispute as to the experimentally observed facts. The confusion must therefore be attributable to differences in definitions, terminology, and/or the meanings attached to algebraic symbols. If the definitions, terms and symbols can be standardized, the controversies should disappear.

Magnetic terminology has apparently been built up on three different series of experimental phenomena that followed in historical sequence:

(*A*) The magnetic phenomena of permanent magnets, up to the year 1820 and prior to Oersted's discovery of electromagnetic action.

(*B*) Electromagnetic phenomena involving currents and magnets.

(*C*) The circuital phenomena of magnetic circuits, since about 1870.

The (*A*) phenomena were mathematically analyzed by Coulomb, Gauss, and researchers in the permanent or semipermanent magnetism of steel and iron. The (*B*) phenomena were analyzed by Weber, Ampère, Maxwell and many of their followers. The (*C*) phenomena were analyzed mainly by magneto-technicians like Hopkinson and Frolich, in the development of dynamo machines.

Scientific definitions in magnetism were originally built upon the (*A*) basis, which became classical. It is not here contended that these classical definitions are incorrect or erroneous. Indeed it is generally admitted that they were excellent at the date of their establishment. But there is a widespread opinion that the classical definitions based upon the inferred behavior of permanent-magnet point-poles are now somewhat out of date, and might advantageously be replaced by definitions on the more modern (*B*) basis. In this paper, a series of magnetic definitions is offered on the still more modern (*C*) basis; not because that is proposed as the best; but because the (*C*) definitions are likely to be remote from, and in contrast with, the existing classical (*A*) definitions. Perhaps international agreement may thereby be aided in reaching satisfactory definitions on an intermediate or (*B*) basis.

Simple Forms of Magnetic Circuit

The simplest form of magnetic circuit is probably the well known toroid, or anchor ring, indicated in Fig. 1. In studying the behavior of non-magnetic material, such a toroidal core is commonly built of wood; but when the behavior is investigated of a magnetic solid substance, such as a particular alloy of steel, the toroid is usually built up of circular rings or laminae of the material. The exciting winding of N turns of insulated wire is supposed to be uniformly distributed around the ring; so that if $L = \pi D$ cm is the mean peripheral length of the core (D being the mean diameter in cm.), the number of turns per cm., $n = N/L$, may be taken as constant. For purposes of measurement, a secondary winding is ordinarily applied over the exciting or primary winding; but the secondary winding and circuit need not here be considered.

The magnetic field outside the wound toroid, or closed circular solenoid, due to its exciting current, is known to be zero, assuming a perfectly symmetrical winding, and a twisted pair of supply wires. All of the field due to the excited winding is within the solenoid. This field is also known to be

non-uniform, being stronger at the inner surface *aa'bb'* than at the outer surface *cc'dd'*, owing to the difference of circumferential length at these surfaces; but if the toroid is given

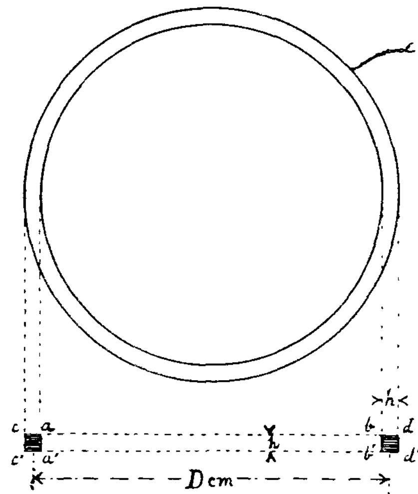


FIG. 1.—Simple toroidal Magnetic Circuit or closed circular solenoid.

a diameter D large with respect to its breadth h, this lack of uniformity can be made as small as is desired. Moreover, if the diameter D be made indefinitely great, any moderate sector length of l cm. will be almost straight; so that provided l is large with respect to the breadth h, the field within this long straight solenoid of n turns per cm. will be almost uniform over the cross-section *aa'bb'*, and will be almost the same as within a corresponding closed circular solenoid of indefinitely large diameter D.

The behavior of non-uniform magnetic fields, in magnetic circuits of complex form and excitation, can always be referred, in principle, to equivalent uniform magnetic fields producible by simple closed circular solenoids or by very long straight solenoids.

Magnetic Circuits of Non-magnetic and of Magnetic Material

It is convenient to divide simple uniform magnetic circuits into two types, namely:

Type I. Those having cores of non-magnetic or *non-ferric* material, corresponding substantially in behavior to vacuum or free space. Such materials are, for practical purposes, air (at ordinary temperatures and pressures), wood and porcelain.

Type II. Those having cores of magnetic or *ferric* material, such as iron, nickel or cobalt; but ordinarily some alloy of iron. These may be called ferric circuits.

In practice, magnetic circuits are commonly of a mixed or composite type, containing non-ferric and ferric elements in series. Composite circuits may be referred, in principle, to equivalent series combinations of simple non-ferric and ferric circuits, each in itself uniform.

Types I and II will be considered separately.

C.G.S. Units Employed in the Discussion

In the following discussion, the units employed will be the classical unrationalized C.G.S. units of the Maxwell magnetic and electric systems. It is customary to employ the classical C.G.S. Magnetic system of units in magnetic calculations of this kind, and to restrict the use of the C.G.S. Electrostatic system to electrical calculations. Either system may, however, be used for one or the other set of phenomena, and it is proposed to use both systems in parallel columns with the computations appearing in the Appendix, partly for numerical checks, and partly because they mutually support each other. The reader need not follow the steps of computation in the electric system if he is not interested in them. In order to lend a semblance of concrete reality to the units of the C.G.S. Electric system, which are nearly all without names, certain distinguishing prefixes may be permitted.

The prefix *ab* before a practical unit indicates the corresponding C.G.S. Magnetic unit. Thus 1 *abvolt* stands for 10^{-8} *volt*.

The prefix *stat* before a practical unit indicates the corresponding C.G.S. Electrostatic unit. Thus 1 *statvolt* stands for 300 *volts* (very nearly).

The prefix *el* before a C.G.S. Magnetic unit indicates the

corresponding C.G.S. Electrostatic unit. Thus 1 *elmaxwell* stands for 3×10^{10} *maxwells* (very nearly).

The prefixes *ab* and *stat* are used to some extent in American literature, especially the *ab*. The prefix *el* is very rarely used. None of these prefixes have been recognized internationally; but they serve to impart definite unitological concepts.

Circuits of Type I, or Non-ferric Circuits

We may assume a closed circular solenoid, as shown in Fig. 1, with a wooden core of mean diameter $D = 47.75$ cm. or mean length $L = \pi D$ of 150 cm. The copper wire winding might have $N = 1500$ turns, uniformly applied so as to give $n = 10$ turns per cm. of mean core length. The active or equivalent core section $c'ca'a$ might be square, and with $h = 2$ cm.; so that the active sectional area of the circuit would be $S = 4$ cm.^{2}. We assume that the wooden core is so nearly non-magnetic, that if replaced by a hollow or tubular glass core exhausted of air, so as to be virtually a vacuum core, no difference in magnetic properties would be appreciable.

We now proceed to apply an exciting current of, say, 5 amperes (0.5 abampere or 1.5×10^{10} statamperes), to the solenoidal winding, and compute the magnetic conditions in the core, both in C.G.S. Magnetic and in C.G.S. Electric Units. Table I in the Appendix presents the well known relations between these two systems of units. The numerical value of the velocity v of electromagnetic propagation, which enters into the ratios between the corresponding units, is taken as $v = 3.0 \times 10^{10}$ cm./sec., a round number sufficiently nearly correct for many practical purposes.

Ohm's Law in Simple Electric and Magnetic Circuits

Ohm's law of the simple voltaic circuit $I = E/R$, when extended to a simple uniform nonferric circuit of Type I, becomes, as is well known:—$\Phi = \mathfrak{F}/\mathfrak{R}$ *maxwells* in C.G.S. Mag.U. or *elmaxwells* in C.G.S.El.U. where, in each system,

$\mathfrak{F}$ is the C.G.S. magnetomotive force (mmf.) impressed on the circuit.

$\mathfrak{R}$ is the C.G.S. reluctance in the circuit.

Φ is the magnetic flux in the circuit.

We may first offer definitions for these terms. The definitions from the standpoint (C) of the magnetic circuit will not be identical with those based on the classical (A) system.

The *magnetic*[1] *flux* Φ in a simple non-ferric circuit, produced by a uniform impressed excitation, is 4π times the total vector mag. displacement m thus passed through the circuit at any cross-section. It may be measured by finding the total quantity of electricity Q induced thereby in a single turn of thin insulated wire enclosing the magnetic circuit and carried out to a suitable galvanometer, through a secondary circuit of total electric resistance R according to the formula:

$\Phi = QR$ *maxwells*, if Q is in *abcoulombs* and R in *abohms;*

or

$\Phi = QR$ *elmaxwells*, if Q is in *statcoulombs* and R is in *statohms*.

The *magnetomotive force* (mmf.) is the physical force which, applied to a magnetic circuit, tends to drive magnetic flux Φ around the circuit.

Mmf.'s are of two kinds:

a. Structural mmf.'s, residing in the substance of permanent or semi-permanent magnets; *i.e.* in magnetic material. Structural mmf.'s pertain to ferric circuits, or circuits of Type II.

b. Electrocircuital mmf.'s associated with active electric conductors and with loops of the same. In simple uniform nonferric circuits, electrocircuital mmf.'s belong to Type I, and are expressed by the relation,

$$\mathfrak{F} = 4\pi NI \begin{cases} \textit{gilberts} \text{ in C.G.S.Mag.U.} \\ \textit{elgilberts} \text{ in C.G.S.El.U.,} \end{cases}$$

[1] In mathematics a flux is ordinarily defined as a surface integral of any vector quantity over an area. In physics, however, magnetic flux may be defined as the particular quantity above mentioned which passes around a magnetic circuit.

where N is the number of active turns applied to the circuit, and I is the exciting current strength, in corresponding C.G.S. units.

The *reluctance* $\mathfrak{R}$ of a simple non-ferric magnetic circuit, or element thereof, is that property of the circuit which opposes the production of magnetic flux Φ, under the action of an impressed mmf., $\mathfrak{F}$.

In any elementary prism of non-ferric material, or free space, the reluctance $\mathfrak{R}$ is

$$\mathfrak{R} = \frac{l}{s}\nu_0 \qquad \text{C.G.S. reluctance units,}$$

where l is the length of the prism in cm. along which the uniform flux passes, s is the cross-section of the prism in cm.^{2}, assumed as perpendicular to the flux, and ν_0 is the reluctivity of vacuum, free space, or non-ferric material. In any system of magnetics, ν_0 is a fundamental physical constant of space, and is called *space-reluctivity*. Its unit has no name, but may be provisionally called the *nu* in the C.G.S.Mag. system and *elnu* in the C.G.S.El. system. The much debated question whether ν_0 has or has not real physical dimensions need not here be discussed; because there are good authorities on each side of the question. It is generally admitted that there are some definitions of magnetic quantities which assign to ν_0 the dimensions of a pure numeric, while there are other magnetic definitions which assign to ν_0 real physical dimensions; or those of a non-numeric. It is sufficient for present purposes to note here the general agreement that in the C.G.S.Mag. system, the numerical value of the *nu* is made equal to unity, for simplicity of computation; while in the C.G.S.El. system, it is necessarily made equal to v^2, where v is the free-space velocity of electromagnetic propagation, and may be taken as 3×10^{10} cm./sec., for many practical purposes.

The reluctance of a simple closed circular non-ferric magnetic circuit of sufficiently large diameter may be taken as $\mathfrak{R} = L\nu_0/S$ reluctance units,[1] where L is the mean circum-

[1] It is known that for a non-ferric toroid of rectangular cross section, with core height h cm. and external-internal radii r_2, r_1 cm., the reluctance of the core corrected for curvature is:

$$\mathfrak{R} = \frac{2\pi\nu_0}{h \operatorname{logh} (r_2/r_1)} \qquad \text{nus/cm.}$$

ferential length in cm., S is the active cross-section in cm.^{2}, and ν_0 is the space reluctivity. In the case of a simple straight non-ferric magnetic circuit of great length, the total reluctance is indefinite; but the linear reluctance is ν_0/S *nus* or *elnus per square cm.*, where S is the effective cross-sectional area of the cylinder in cm.^{2}.

Permeance Form of Magnetic Ohm's Law

Just as Ohm's law in a simple voltaic circuit may be expressed in the form $I = EG$ where G, the conductance of the circuit, is the reciprocal of the resistance R; so Ohm's law extended to a simple magnetic circuit of Type I may be expressed in the form $\Phi = \mathfrak{F}\mathfrak{P}$, where $\mathfrak{P}$ is the permeance of the circuit and is the reciprocal of the magnetic reluctance $\mathfrak{R}$.

In any elementary prism of non-ferric material or free space, the permeance $\mathfrak{P}$ is

$$\mathfrak{P} = \frac{s}{l}\mu_0 \qquad \text{C.G.S. permeance units,}$$

where l is the length of the prism in cm., along which the uniform flux passes, s is the uniform cross-section of the prism in cm.^{2}, and μ_0 is the permeability of vacuum, free space or non-ferric material. It is called *space permeability*, and it is the reciprocal of ν_0, the space reluctivity. There is no name for the unit of this space constant; but it may be referred to as the *mu* in the C.G.S.Mag. system and as the *elmu* in the C.G.S.El. system. Its physical dimensions, being in debate, are not considered here; but it is assigned the numerical value unity in the Magnetic System, and the value $1/v^2$ or approximately $\frac{1}{9} \times 10^{-20}$ in the Electric System.

The permeance of a simple closed circular non-ferric circuit, of diameter large with respect to core breadth, may be taken as $\mathfrak{P} = S\mu_0/L$ permeance units. In the case of a very long straight cylindrical circuit, the linear permeance may be taken as $S\mu_0$ permeance units in each cm. of length, if the circuit is non-ferric. If the number of active turns per linear cm. is n, the linear mmf. of the straight solenoid will be $4\pi nI$ *gilberts* in C.G.S.Mag.U. and the flux in the very long straight

core may be taken as uniform and equal to

$$\Phi = 4\pi nIS\mu_0 \qquad \textit{maxwells.}$$

A *magnetic field* is a space distribution of magnetic flux Φ. It commonly happens that in any particular region of space, the flux distribution is produced by several mmf.'s acting independently. If we confine attention to one mmf., the field due to that mmf., in the region considered, may be called its *intrinsic field;* while the field due to the other mmf. or mmf.'s may be called the *extrinsic field.* The *total field* will then be the vector sum of the intrinsic and extrinsic fields. Thus, within the core of a non-ferric closed circular solenoid, there may be the intrinsic field of the solenoid, and the extrinsic field of the earth, or of some other mmf. in the neighborhood. As is well known, it is often possible to distinguish quantitatively the intrinsic field of an impressed mmf. from the extrinsic field, by suitable technique.

Magnetic flux Φ is known to be a vector quantity, and is capable of being specified, at any point of a field, by its intensity and its direction. The intensity of the flux is commonly called the flux density B. In uniform magnetic flux, the flux paths being parallel, the *flux density* $B = \Phi/S$, where Φ is the quantity of flux passing perpendicularly through a plane intersecting surface area of S cm.^{2}. In non-uniform flux, with the flux paths not parallel, the density B at any point is $d\Phi/dS$, where $d\Phi$ is the small element of flux passing perpendicularly through a correspondingly small surface of dS cm.^{2}. In the case of simple uniform non-ferric magnetic circuits, of either the toroidal or long cylindrical type, a suitable exploring loop of wire can be inserted into the magnetic circuit, and led out to a galvanometer, in such a manner as to enable B to be measured both in direction and in magnitude. If the core of non-ferric material should be solid, a groove or cavity might have to be cut in it, for the admission of the exploring ring, without thereby disturbing the magnetic flux or flux density to be measured or injuring the mechanical integrity of the core structure.

The *linear mmf.* H of a simple non-ferric magnetic circuit, either of the closed circular or long cylindrical type, is

$$H = \frac{\mathfrak{F}}{L} = 4\pi nI \qquad \textit{gilberts per cm.} \text{ in C.G.S.Mag.U.}$$

By international agreement, the *oersted* is an alternative name for the C.G.S. Magnetic Unit of H. In simple non-ferric circuits, we have the relation

$$B = \mu_0 H \qquad \textit{gausses} \text{ in C.G.S.Mag.U.}$$

Because space permeability μ_0 is made unity in the Magnetic System, it follows that the numerical value of the flux density B will be the same as that of the linear mmf. H. In all[1] other unit systems, however, including the C.G.S. Electric system, the numerical values of B and H differ. In the discussion of ferric and of composite magnetic circuits, it will be seen that the linear mmf. H is also a *gradient of magnetic potential*, a *magnetizing force* and a *magnetic intensity;* but in non-ferric circuits, H plays a subordinate part relatively to B.

Simple Magnetic Circuits of Type II. Ferric Circuits

If we replace the wooden core of the simple toroidal circuit in Fig. 1 by a uniform iron core, using the same winding and excitation, we know that with the same impressed mmf. $\mathfrak{F}$ as before, we obtain a flux Φ' in the core, that may be hundreds of times greater than was produced in the wooden core. But whereas the non-ferric flux Φ increased directly with the impressed mmf., the new ferric flux Φ' does not increase directly with $\mathfrak{F}$; but approaches a saturation value, and has to be determined experimentally from point to point, along a saturation curve, as $\mathfrak{F}$ is increased by suitable steps. How is this well known behavior of the ferric circuit to be interpreted?

Following the Ohm's law analogy, the increase in Φ' over Φ at a given value of the mmf. must be attributed either to an increase of circuit permeance, or to an increase in mmf., or to both causes combined. If the flux increase were due entirely to greater permeance in iron, as compared with wood,

[1] An exception should be noted for the Q.E.S. system, in which $\mu_0 = 1$.

we should expect to find no trace of flux left in the iron core, when the mmf. of excitation is withdrawn. We find, however, that depending upon the magnetic hardness of the iron core, a considerable part of the extra flux persists in the circuit. In some cases the residual magnetic flux may be 80 per cent, or more, of the total flux produced in the ferric circuit. We infer, therefore, that the increase in the flux is due, at least in greater part, to an increase in mmf. It is thus reasonable to assume that the impressed mmf. of excitation induces an auxiliary structural mmf. in the iron; while the permeance of the magnetic circuit is the same as in the non-ferric case. There is thus a structural or ferric mmf. in the iron, aiding the impressed mmf. of excitation.

If then, at a given stage of impressed mmf. $\mathfrak{F}$ *gilberts*, the flux in the ferric circuit is r times greater than in the same toroidal non-ferric circuit, it is reasonable to suppose that the total mmf. has become $r\mathfrak{F}$ *gilberts*, and the linear mmf. $r\mathfrak{F}/L = rH$ *gilberts per cm.* or rH *oersteds*. With the permeance $\mathfrak{P} = S\mu_0/L$, the magnetic flux would become $\Phi' = r\Phi = r\mathfrak{F}\mathfrak{P} = r\mathfrak{F}S\mu_0/L$ *maxwells*, with a uniform flux density $B' = rB = \mu_0 H' = r\mu_0 H$ *gausses*. If we define $r\mu_0$ as the *absolute permeability* μ of the ferric circuit, we have the well known relations:

$$\Phi' = \mathfrak{F}S\mu/L = HS\mu \qquad \textit{maxwells}$$

and

$$B' = H\mu \qquad \textit{gausses.}$$

Moreover, $r = \mu/\mu_0$ is called the *relative permeability*, and is, by assumption, a numerical quantity.

We may therefore treat the ferric circuit as though the only mmf. acting on it was the impressed excitation $\mathfrak{F}$, and with the permeance increased r times. This is a convenient working hypothesis, so long as we do not have to consider the residual magnetic flux when the excitation $\mathfrak{F}$ is withdrawn.

Interlinked Ferric and Non-ferric Circuits

A *permanent magnet* is a mass of ferric material containing a structural mmf. which is assumed to be permanent; *i.e.* not

to vary with time, under normal conditions of treatment. It has a magnetic circuit partly inside and partly outside its mass, which is ordinarily surrounded with uniform non-ferric material, such as air. A common form of permanent magnet is that of a long straight thin bar or wire-needle. A *magnetic needle* may, for this purpose, be defined as a steel wire, of length many times greater than its diameter. To a first approximation, the magnetic field of a needle lies entirely within it, except at its ends or poles. In other words, the magnetic flux in the circuit of the needle may be taken, for many practical purposes, as uniform within the needle, under a uniform linear structural mmf. $\mathfrak{F}$, and emerging into the air at its polar extremities. At external distances, large with respect to the needle's length l cm., the flux Φ in the external part of the circuit may be assumed to be distributed as though each pole was a small sphere, or magnetic point source, carrying a quantity of magnetism $m = \Phi/4\pi$ C.G.S. pole units, the north-seeking end being taken as $+ m$ and the south-seeking end as $- m$, the two being maintained separate at the distance l, by the needle's mechanical structure.

When the needle is introduced into a steady extrinsic non-ferric magnetic field, the needle's magnetic field, assumed to be constant, merges with it to produce a resultant total field, in which the flux density at any point is B *gausses*. The volume energy of the resultant field at each point is $B^2/8\pi\mu_0$ ergs/cm.^{3}. It is known that tensions, developed in the non-ferric medium, will be exerted upon the needle's magnetic circuit, tending to displace it with respect to the extrinsic field, until the integrated volume energy of the total field attains a maximum.

It is also recognized that the forces acting on the needle are equivalent to those produced on each of its poles by the local gradients H of magnetic potential in the extrinsic field, according to the expression $f = Hm$ *dynes*. For the purposes of that interpretation, the extrinsic field may be conveniently visualized as dual:—

(*a*) a vector distribution of magnetic flux Φ, with its local vector density B at each point.

(*b*) a scalar distribution of magnetic potential $\mathfrak{F}$, measured in *gilberts*, with the vector gradient H of the same, at each point, measured in *gilberts per cm.* or *oersteds.* In simple non-ferric circuits, the (*a*) and (*b*) fields have similar distribution forms, since at each point, $B = \mu_0 H$. But in ferric or mixed circuits, the (*a*) and (*b*) distributions may be dissimilar. In any air-gap, however, where the circuit becomes locally non-ferric, the (*a*) and (*b*) distributions become similar once more, being in simple numerical ratio through the space constant μ_0. The stresses and tensions developed on ferric masses introduced into the magnetic field at such an air-gap, may be explained either on the basis of distortions in the (*a*) distribution; or by resorting to the polar hypothesis using the (*b*) field.

Summary of Conclusions

(1) In (*C*) theory, or non-ferric circuit theory, a "magnetic field" may be defined entirely with reference to vector physical magnetic flux Φ and its local vector density B *gausses.* The conception of a field of H is then subsidiary, and may even be superfluous.

(2) In simple non-ferric circuits, the essential quantities that call for definition are (*a*) the mmf. $\mathfrak{F}$, (*b*) the reluctance $\mathfrak{R}$ and (*c*) the flux Φ. The reluctance may be defined in terms of circuit dimensions and the space reluctivity ν_0, which is a fundamental constant of space.

(3) In simple non-ferric circuits, we may also define the permeance $\mathfrak{P}$ as the reciprocal of the reluctance $\mathfrak{R}$ and derive the permeance from the circuit dimensions and the space permeability $\mu_0 = 1/\nu_0$.

(4) In simple ferric magnetic circuits, the increase in magnetic flux Φ over that producible in a non-ferric circuit of like dimensions and excitation, is probably attributable to an increase in mmf. $\mathfrak{F}$ in the circuit, and not to increase of permeance. In that sense, the increase in Φ is probably attributable to an increase in H, the gradient of $\mathfrak{F}$. For practical purposes, however, it is convenient to assume that the space permeability μ_0 of the circuit has become increased to the so-called absolute permeability μ.

(5) In interlinked magnetic circuits, the observed magneto-mechanical stresses may be conveniently explained by the hypothesis of solitary magnetic poles, with forces exerted on them of the type $f = Hm$. This hypothesis justifies the definition of H as being one element of an interlinked field.

(6) Whereas therefore the classical (A) theory, dealing with the forces exerted upon permanent magnets, emphasized the presence of H in a magnetic field, and derived B therefrom as a secondary effect in ferric material, the circuital (C) theory emphasizes the presence of B in a magnetic field, and derives H therefrom as a device for dealing with ferric mechanical forces. It is not contended here that (C) is right and (A) wrong; but merely that they offer two opposite viewpoints of the same experimental phenomena. Perhaps intermediate (B) theory may serve as a basis for a set of definitions finally satisfactory to all magneticians. Such a set of universally acceptable definitions is much needed, in order to harmonize magnetic opinion internationally.

(7) None of the magnetic-circuit definitions offered in this paper, taken singly, is claimed to be new. All of them are found, either expressed or implied, in magnetic literature. Therefore, the only novelty that can be claimed here for them is their collection into a consecutive series.

(8) Circuital definitions are offered for the magnetic quantities ordinarily represented by the symbols Φ, $\mathfrak{F}$, $\mathfrak{R}$, ν_0, $\mathfrak{P}$, μ_0, B, H, $\mathfrak{L}$, μ, m and μ/μ_0. No modifications are suggested for the classical definitions of susceptibility κ and intensity of magnetization $\mathfrak{J}$.

APPENDIX. NUMERICAL DATA FOR NON-FERRIC CIRCUIT OF FIG. 1 COMPUTED BOTH IN C.G.S. MAGNETIC UNITS AND IN C.G.S. ELECTRIC UNITS

(a) Magnetomotive Force $\mathfrak{F}$ with 5 Amperes Excitation

Formula $\mathfrak{F} = 4\pi NI$

C.G.S.Mag.U.	C.G.S.El.U.
$4\pi = 12.57$	$4\pi = 12.57$
$N = 1500$ turns	$N = 1500$ turns
$I = 0.5$ *abampere*	$I = 1.5 \times 10^{10}$ *statamperes*
$\mathfrak{F} = 12.57 \times 1.5 \times 10^3 \times 0.5$	$\mathfrak{F} = 12.57 \times 1.5 \times 10^3 \times 1.5 \times 10^{10}$
$= 9.425 \times 10^3$ *gilberts*	$= 28.27 \times 10^{13}$ *elgilberts*

(*b*) Reluctance $\mathfrak{R}$

$$\text{Formula } \mathfrak{R} = \frac{L\nu_0}{S}$$

$\nu_0 = 1$ *nu*
$L = 150$ cm.
$S = 4$ cm.^{2}
$$\mathfrak{R} = \frac{150 \times 1}{4} = 37.5 \textit{ nus/cm.}$$

$\nu_0 = 9 \times 10^{20}$ *elnus*
$L = 150$ cm.
$S = 4$ cm.^{2}
$$\mathfrak{R} = \frac{150 \times 9 \times 10^{20}}{4} = 3.375 \times 10^{22} \textit{ elnus/cm.}$$

(*c*) Permeance $\mathfrak{P}$

$$\text{Formula } \mathfrak{P} = \frac{S\mu_0}{L}$$

$\mu_0 = 1$ *mu*
$S = 4$ cm.^{2}
$L = 150$ cm.
$$\mathfrak{P} = \frac{4 \times 1}{150} = 2.667 \times 10^{-2} \textit{ mu cm.}$$

$\mu_0 = 10^{-20}/9$ *elmus*
$S = 4$ cm.^{2}
$L = 150$ cm.
$$\mathfrak{P} = \frac{4 \times 10^{-20}}{150 \times 9} = 2.963 \times 10^{-23} \textit{ elmu cm.}$$

(*d*) Flux

$$\text{Formula } \Phi = \mathfrak{F}\mathfrak{P} \text{ or } \Phi = \mathfrak{F}/\mathfrak{R}$$

$\mathfrak{F} = 9.425 \times 10^3$ *gilberts*
$\mathfrak{P} = 2.667 \times 10^{-2}$ *mu cm.*
$\Phi = 9.425 \times 10^3 \times 2.667 \times 10^{-2}$
$\quad = 2.513 \times 10^2$ *maxwells*

$\mathfrak{F} = 28.27 \times 10^{13}$ *elgilberts*
$\mathfrak{P} = 2.963 \times 10^{-23}$ *elmu cm.*
$\Phi = 28.27 \times 10^{13} \times 2.963 \times 10^{-23}$
$\quad = 0.8376 \times 10^{-8}$ *elmaxwells*

(*e*) Flux Density B, Assumed Uniform

$$\text{Formula } B = \frac{\Phi}{S}$$

$\Phi = 2.513 \times 10^2$ *maxwells*
$S = 4$ sq. cm.
$$B = \frac{2.513 \times 10^2}{4} = 62.83 \textit{ gausses}$$

$\Phi = 0.8376 \times 10^{-8}$ *elmaxwells*
$S = 4$ sq. cm.
$$B = \frac{0.8376 \times 10^{-8}}{4} = 2.094 \times 10^{-9} \textit{ elgauss}$$

(*f*) Inductance of Winding $\mathfrak{L}$

$$\text{Formula } \mathfrak{L} = \frac{\Phi N}{I}$$

$\Phi = 2.513 \times 10^2$ *maxwells*
$N = 1.5 \times 10$ turns
$I = 0.5$ *abampere*
$$\mathfrak{L} = \frac{2.513 \times 10^2 \times 1.5 \times 10^3}{0.5}$$
$\quad = 7.540 \times 10^5$ *abhenrys*

$\Phi = 0.8376 \times 10^{-8}$ *elmaxwells*
$N = 1.5 \times 10^3$ turns
$I = 1.5 \times 10^{10}$ *statamperes*
$$\mathfrak{L} = \frac{0.8376 \times 10^{-8} \times 1.5 \times 10^3}{1.5 \times 10^{10}}$$
$\quad = 0.8376 \times 10^{-15}$ *stathenry*

(g) Electromagnetic Energy in Excited Winding of Non-ferric Circuit

$$\text{Formula } W = \frac{\mathfrak{L} I^2}{2} \textit{ ergs}$$

C.G.S.Mag.U.

$\mathfrak{L} = 7.540 \times 10^5$ *abhenrys*
$I^2 = 0.25$ *abampere*^{2}
$W = \dfrac{7.540 \times 10^5 \times 0.25}{2}$
$= 0.9425 \times 10^5$ *ergs*

C.G.S.El.U.

$\mathfrak{L} = 0.8376 \times 10^{-15}$ *stathenry*
$I^2 = 2.25 \times 10^{20}$ *statampere*^{2}
$W = \dfrac{0.8376 \times 10^{-15} \times 2.25 \times 10^{20}}{2}$
$= 0.9425 \times 10^5$ *ergs*

(h) Volume Energy in Non-ferric Circuit

$$\text{Formula } w = \frac{B^2}{8\pi\mu_0} \textit{ ergs/cm.}^3$$

$B = 62.83$ *gausses*
$B^2 = 3.946 \times 10^3$ *gausses*^{2}
$8\pi = 25.13$
$\mu_0 = 1$ *mu*
$w = \dfrac{3.946 \times 10^3}{25.13 \times 1} = 1.5708 \times 10^2$ *ergs/cm.*^{3}

$B = 2.094 \times 10^{-9}$ *elgauss*
$B^2 = 4.385 \times 10^{-18}$ *elgauss*^{2}
$8\pi = 25.13$
$\mu_0 = 10^{-20}/9$ *elmu*
$w = \dfrac{4.385 \times 10^{-18} \times 9}{25.13 \times 10^{-20}} = 1.5708 \times 10^2$ *ergs/cm.*^{3}

(i) Total Volume Energy in Non-ferric Circuit

$$\text{Formula } W = Vw \textit{ ergs}$$

$V = Lk^2 = 6.00 \times 10^2$ *cm.*^{3}
$w = 1.5708 \times 10^2$ *ergs/cm.*^{3}
$W = 6.00 \times 10^2 \times 1.5708 \times 10^2$
$= 9.4248 \times 10^4$ *ergs*

$V = Lk^2 = 6.00 \times 10^2$ *cm.*^{3}
$w = 1.5708 \times 10^2$ *ergs/cm.*^{3}
$W = 6.00 \times 10^2 \times 1.5708 \times 10^2$
$= 9.4248 \times 10^4$ *ergs*

(j) Gradient of Potential H in Non-ferric Circuit, or Magnetizing Force in a Ferric Circuit

$$\text{Formula } H = \mathfrak{F}/L \textit{ gilberts/cm.}$$

$\mathfrak{F} = 9.425 \times 10^3$ *gilberts*
$L = 1.5 \times 10^2$ *cm.*
$H = \dfrac{9.425 \times 10^3}{1.5 \times 10^2} = 6.283 \times 10$ *gilb./cm.*

$\mathfrak{F} = 28.27 \times 10^{13}$ *elgilberts*
$L = 1.50$ *cm.*
$H = \dfrac{28.27 \times 10^{13}}{1.5 \times 10^2} = 18.85 \times 10^{11}$ *elgilberts/cm.*

(k) Force Exerted on Pole of $m = 1$ *Pole* $= 10^{-10}/3$ *Elpoles* Inserted in a Non-ferric Circuit

$$\text{Formula } f = Hm \textit{ dynes}$$

$H = 6.283 \times 10$ *gilberts/cm.*
$m = 1$ *pole*
$f = 6.283 \times 10$ *dynes*

$H = 18.85 \times 10^{11}$ *eloersteds*
$m = 10^{-10}/3$ *elpoles*
$f = 18.85 \times 10^{11} \times 10^{-10}/3$
$= 6.283 \times 10$ *dynes*

(*l*) Force between Two Poles in Air, Each of $m = 60$ *Poles* at $r = 20$ *cm*. Distance

$$\text{Formula } f = \frac{m^2}{\mu_0 r^2}\ \textit{dynes}$$

$$m = 60\ \textit{poles} \qquad\qquad m = 20 \times 10^{-10}\ \textit{elpoles}$$

$$m^2 = 3.6 \times 10^3\ \textit{poles}^2 \qquad\qquad m^2 = 4 \times 10^{-18}\ \textit{elpoles}^2$$

$$r^2 = 4 \times 10^2\ \textit{cm.}^2 \qquad\qquad r^2 = 4 \times 10^2\ \textit{cm.}^2$$

$$\mu_0 = 1\ \textit{mu} \qquad\qquad \mu_0 = 10^{-20}/9\ \textit{elmu}$$

$$f = \frac{3.6 \times 10^3}{1 \times 4 \times 10^2} = 9.0\ \textit{dynes} \qquad\qquad f = \frac{4 \times 10^{-18} \times 9}{10^{-20} \times 4 \times 10^2} = 9.0\ \textit{dynes}$$

TABLE OF EQUIVALENTS BETWEEN C.G.S. MAGNETIC UNITS AND C.G.S. ELECTROSTATIC UNITS IN THE CLASSICAL SYSTEMS

No.	Symbol	Quantity	C.G.S.Mag. = n C.G.S.El.U.	C.G.S.El.U. = $1/n$ C.G.S.Mag.U.
1	E	E.M.F.	1 *Abvolt* = $1/v$ *Statvolt* ($10^{-10}/3$)	1 *Statvolt* = 3×10^{10} *Abvolts*
2	R	Resistance	*Abohm* = $1/v^2$ *Statohms* ($10^{-20}/9$)	*Statohm* = 9×10^{20} *Abohms*
3	I	Current	*Abampere* = v *Statamp.* (3×10^{10})	*Statamp.* = $10^{-10}/3$ *Abampere*
4	Q	Quantity	*Abcoulomb* = v *Statcoul.* (3×10^{10})	*Statc.* = $10^{-10}/3$ *Abcoulomb*
5	C	Capacitance	*Abfarad* = v^2 *Statfarad* (9×10^{20})	*Statf.* = $10^{-20}/9$ *Abfarad*
6	S	Elastance	*Abdaraf* = $1/v^2$ *Statda.* ($10^{-20}/9$)	*Statda.* = 9×10^{20} *Abdarafs*
7	ϵ_0	Permittivity	Mag.U. = v^2 Stat.U. (9×10^{20})	Stat.U. = $10^{-20}/9$ Mag.U.
8	$\mathfrak{L}$	Inductance	*Abhenry* = $1/v^2$ *Stath.* ($10^{-20}/9$)	*Stath.* = 9×10^{20} *Abhenries*
9	μ_0	Permeability	*Mu* = $1/v^2$ *Elmus* ($10^{-20}/9$)	*Elmu* = 9×10^{20} *Mus*
10	$\mathfrak{F}$	M.M.F.	*Gilbert* = v *Elgilberts* (3×10^{10})	*Elgil.* = $10^{-10}/3$ *Gilberts*
11	$\mathfrak{R}$	Reluctance	Mag.U. = v^2 Stat.U. (9×10^{20})	Stat.U. = $10^{-20}/9$ Mag.U.
12	ν_0	Reluctivity	*Nu* = v^2 *Elnus* (9×10^{20})	*Elnu* = $1/v^2 = 10^{-20}/9$ *Nus*
13	Φ	Flux	*Maxwell* = $1/v$ *Elmaxwell* ($10^{-10}/3$)	*Elmax.* = 3×10^{10} *Maxwells*
14	H	Magnetizing Force	*Oersted* = v *Eloersteds* (3×10^{10})	*Eloersted* = $10^{-10}/3$ *Oerst.*
15	B	Flux Density	*Gauss* = $1/v$ *Elgauss* ($10^{-10}/3$)	*Elgauss* = 3×10^{10} *Gauss*
16	$\mathfrak{P}$	Permeance	Mag.U. = $1/v^2$ Stat.U. ($10^{-20}/9$)	Stat.U. = 9×10^{20} Mag.U.
17	m	Pole Strength	*Pole* = $1/v$ *Elpoles* ($10^{-10}/3$)	*Elpole* = 3×10^{10} *Poles*
18	$\mathfrak{J}$	Mag. Intensity	*Poles/cm.*^{2} = $1/v$ *Elpoles/cm.*^{2}	*Elpole/cm.*^{2} = 3×10^{10} *P/cm.*^{2}
19	κ	Susceptibility	Mag.U. = $1/v^2$ Stat.U. ($10^{-20}/9$)	Stat.U. = 9×10^{20} Mag.U.
20	W	Energy	*Erg*	*Erg*
21	P	Power	*Erg/Sec.*	*Erg/Sec.*
22	L	Length	*Centimeter*	*Centimeter*
23	M	Mass	*Gram*	*Gram*
24	T	Time	*Second*	*Second*
25	F	Force	*Dyne*	*Dyne*

THE GROWING OVERHEAD IN GOVERNMENT

JAMES T. YOUNG

(Read April 22, 1933)

One favorable aspect of the era into which we have now plunged is the greater openness of men's minds. We are fast developing under pressure, a willingness, heretofore little known, to inspect, to criticize, to evaluate our political institutions and to consider the possibility of improvement. In doing so we are led to ask whether some of our political assets are not in truth liabilities, and whether certain mechanisms which we have long used, require at least a careful readjustment lest they become obstacles to further progress.

There is a striking analogy between our efforts to reorganize certain insolvent parts of the business structure and similar efforts in the political field. The first step in business reorganization is the scaling down of a staggering load of financial debts, to a plane which will allow the enterprise to operate. In government we are beginning to scale down certain liabilities due to obsolescence. Both are attempts to reduce the overhead. In business we have excessive unpaid taxes, mortgage interest, excessive salaries, wages and rents. These have dissipated and destroyed the productive resources of the enterprise. In government we have excessive division of authority, confused administrative practices, sharp conflicts of power, and much needless duplication of machinery—all inherited from an earlier time when conditions were notably different from our own. In business, excessive debt, in government, excessive obsolescence, are the chief items of overhead which now occupy the attention of the reorganizer. In all our discussions of obsolete government, chief importance has been attached to the need of reducing budgets. Yet far greater than the financial costs of obsolescence is that less perceptible but more dangerous cost that comes because the

work of government is left undone and from the ability of government to meet new needs being paralyzed or destroyed. Financial costs are dramatic and impressive. Inefficiency costs are less visible but more far-reaching in their permanent effects.

Let us then resolve ourselves for a few moments into an impartial jury and summoning before us some obsolescent features of our system, note their relation to the growing overhead of government, and let us then select some one of these features for more detailed scrutiny.

The first point at which obsolescence has become clear is the theory that all voters should participate in all important political decisions. This is an extreme conclusion, drawn in later years, from Jefferson's theory of democracy. Jefferson himself would probably not accept it. He placed great dependence upon the popular masses it is true, and sought to broaden the base of government so as to include them. But he did not believe in the extensive development of industry nor in the turbulent riotous city population which it created. His faith was based upon an agricultural democracy. Nevertheless the extreme and distorted form of his theory stands today as a cornerstone of our political practices. Popular decision on both men and measures is taught in most of the schools, colleges and textbooks of our time.

Last November the voters of Oregon were called on to decide the following questions:

Shall a taxpayer qualification be required for voting?

Shall criminal trials without juries by consent of accused be authorized?

Shall taxes be limited to 6 per cent of the value of property for the three years preceding?

Shall the state prohibition law be repealed?

Shall the state have perpetual title to water power sites and shall it engage in the hydro-electric business?

Shall a tax be laid on oleomargarine?

Shall commercial fishing be allowed in the Rogue River?

What shall be the appropriations for higher education?

Shall the freight truck and passenger bus business be regulated?

Shall the university, normal and law schools be moved and shall junior colleges be established?

Shall the limits of indebtedness be changed?

Shall local taxation be supervised by the state?

Shall the personal income tax be increased and property taxes lowered?

All these decisions were in addition to the regular choice of state and national officers.

The writings of Lawrence Lowell, Walter Lippmann, Richard W. Childs, Seba Eldredge, Peter Odegard and a host of others have conclusively shown that the people will not and cannot do this work. The reaction against the theory goes far beyond the so-called short ballot movement; it goes to the foundation of the theory itself, and is expressed in Walter Lippmann's statement that the public cannot decide even a fraction of our present political questions, that the utmost it can do is to observe certain samples of conduct by public men, to approve or to disapprove, and to entrust the government to those whom it approves—all this without any pretense of considering a lengthy or detailed program of action. It is not unlikely that the efficiency of government and even the safety and welfare of large numbers of our people may depend upon our recognition that the older doctrine no longer fits our conditions.

A second feature which deserves examination is the retention of units of government which no longer fit present means of travel and communication. Forty years ago a prominent economist, Dr. Simon N. Patten, pointed out that our state lines were not then and never had been suitable boundaries for government units, that the running of an arbitrary line by a surveyor's compass could not divide the economic, social and political interests of the people on opposite sides of the line and that even the inhabitants of a river valley had similar interests requiring a common government authority, although rivers marked the boundaries of

many of our states. The original choice of arbitrary and unreal state boundaries was in itself an inconvenience but how much greater is this inconvenience now that the people of broad areas have been drawn together by scientific inventions which are already a commonplace in our lives. Our state boundaries are obsolete. The state areas should be broadened out into larger regions of local autonomy, comprising parts or all of several states in each region, and thus forming a genuine basis for federal decentralization.

The same type of obsolescence is seen in the continuance of limited areas of local government. Why, it has been pertinently asked, should a citizen be smothered under from six to eight layers of government when by simplification, consolidation and otherwise, one half that number would be ample? This is to be intensively discussed by another speaker and we may pass it by with the remark that it is typical of almost our entire machinery of government.

Third, let us now turn to that part of our national government in which the most marked signs of obsolescence are discernible, viz., the relations between the executive and legislative departments.

Our conventional theory of these relations, as expounded by publicists and as taught throughout our educational system is that our national legislature represents the people, that it is an effective and sorely needed check upon those usurpations which the executive is prone to practice and that by controlling taxation, by limiting appropriations, by constant exposure of executive abuses and by jealously guarding the public interests, it and it alone can preserve the priceless liberties of the people. Under this theory the senator or representative being in close touch with the masses of his constituency, is better able to grasp and to present popular views and interests He is therefore distinctly representative. The executive on the contrary, habitually residing at the seat of government, chosen by an indirect method, prone to all the well-known weaknesses of one-man power, and remote from the masses, ought always to be subject to strict supervision and limitation

by Congress. Woodrow Wilson stated that despite all the efforts of the Fathers to preserve an internal balance of power our government has become one of congressional supremacy.

Has this feature of our system also reached the point of obsolescence? Growing numbers of our people are deeply disturbed by the apparent breakdown of legislative deliberation. What they do not realize is that this is true not only in events of the moment but over a long period of years. Concerning the fact of congressional debility there can be no question but there is wide diversity of opinion as to the cause. Two main approaches to the problem have presented themselves, one starting from the point of view of personnel and pointing to the decline which is believed to have taken place in the membership of both houses. From this point of view a whole series of proposals for improvement have been made, reaching down to the detailed mechanism of committee operation, direct election of senators, reduction in the number of members, proportional representation, etc. There is great merit in all these analyses. One thought runs through all of them, namely that congressmen are personally less capable than they used to be, hence legislatures have declined. The behavior of congressmen themselves lends more than a little support to this theory. It has also the advantage of great simplicity, it can be readily grasped by the public mind and forms a convenient stopping place in the discussion of methods for constitutional improvement. Let us send better men to congress and the government will then be restored to its former place of confidence and respect and to its former efficiency.

The other approach is based on a long series of painstaking observations, both here and abroad; it involves a more intensive analysis and bases its conclusions upon a much broader range of data. Seen from this angle the major forces which are now undermining legislative supremacy are the political bloc and the increase of government tasks. Each bloc in the legislative assembly represents the special interests of an economic, social, religious or racial group

among the people. Our methods of propaganda have now reached such perfection that each of these popular special interests has been given a strong group consciousness and has been able to secure its corresponding representatives in political life. Above all, each group or political bloc places its special interests above those of the party to which it may temporarily belong; it lays down its ultimatum to the party leaders and threatens to desert forthwith unless its demands are granted. The majority party in every great nation today is thus confronted with a difficult if not insoluble problem—how can the little blocs and factions be molded into a cohesive organization to retain majority control in the legislative assembly? How can the shipping subsidy bloc, the shipbuilding loan bloc, the soldiers bonus bloc, the manufacturers bloc, the union labor bloc, the farm bloc, the silver mining bloc, the dry bloc, the wet bloc, the inflationist bloc and the sound money bloc be all welded together for united continuous action on a party program? The answer is, they cannot.

May we then pause here a moment to ask two questions? What is the effect of political blocs upon the lawmaking assembly and what is their effect upon the mass psychology of the people?

The first effect of blocs is a progressive paralysis in the legislative assembly. The legislative majority being threatened with dissolution at any moment by the desertion of some influential faction, it becomes necessary for the party leaders to tread the path of cautious compromise, lest they suddenly find themselves in a minority. This means a weak and vacillating policy guided by timidity. The greater the clash of economic, social, religious, or racial interests, the greater must be the care not to offend any group and the greater the inactivity on vital issues. We might go even farther and even say that on numerous recent occasions both here and abroad, the greater the need for action, the greater has been the paralysis of bloc dictation. But our whole system of legislative supremacy has been based upon the

existence of a strong, vigorous and responsible majority party. When this majority party control disappears, the very foundation of congressional supremacy goes with it. When the two-party system with its effective, dependable, party discipline, dissolves in a chaos of blocs, the strength, the vigor and the efficiency of the legislative assembly pass out. When the legislative machine is no longer able to adapt itself to new conditions, obsolescence has begun.

What is the effect on the psychology of the people? In America, England and on the continent there has been a steady and rapid decline of popular confidence in representative institutions. The inability of lawmaking assemblies to fulfill their promises, to meet urgent needs, to formulate vigorous policies is only equaled by their interminable debates and palavers over insignificant trifles. So complete is the popular disillusionment that, as we have seen, many are inclined to blame the personnel of the legislative assemblies for the failure. But this purely personal explanation of congressional weakness appears insignificant when we consider the devastating effects of bloc control. Meanwhile it seems almost a paradox that at the precise moment in history when blocs have brought representative legislatures to their lowest ebb, there should arise the greatest demand for strong legislative action which has ever been witnessed in times of peace. Each nation thinks its own experience peculiar and special, but in truth the phenomenon is world-wide in its scope.

Fortunately a long list of observers throughout Europe have been setting down the facts connected with the collapse of representative government. Delaisi, Cambo, Villari, and Maura with many others equally well known have offered their descriptions and explanations. While their opinions diverge, their facts coincide. No successful attempt at synthesis has thus far been made. But in all the factual descriptions, some of which are quite detailed, the two features which we have noted appear with convincing unanimity—first the rise of economic, social, racial and religious special

interests, strongly organized by propaganda and faithfully reflected in compact uncompromising blocs within the political parties and the legislature, and second the rise of imperative demands for effective far-reaching government action.

Everywhere the answer has been the same—the concentration of political power. Everywhere this has first been presented as a momentary change for a supposed temporary emergency. Did time allow, it would be both instructive and interesting to analyze the many forms which this concentration has assumed.

In America we have almost universally taken for granted that the present concentration of presidential influence arises from an emergency—an emergency in the sense that sudden and unforeseen events crowding upon us have called for a temporary concentration of authority. To those who feel disturbed over the almost complete abdication of the deliberative function in government, the answer is given—"emergency." But with the exception of the unemployment crisis and possibly some very limited aspects of the banking situation, there has been no such sudden crowding of unexpected events but rather a weak, vacillating postponement of essential lawmaking for over ten years due to the obstructions and delays of bloc government. The first, and in many respects the most dramatic, of the emergency steps taken under the new concentration of power has been the rapid reduction of all important items in the budget and the effort to reorganize the federal administrative system. In no sense can this be described as an emergency. For twenty years our presidents have been recommending reorganization to effect greater efficiency and economy and have at last in desperation asked that since congress could not do it the executive be allowed to do so. No clearer instance can be given in which concentrated executive action is called for by legislative debility. The sudden and equally dramatic move in leaving the gold standard, insofar as it is a step towards greater bargaining power in international trade conferences is another action of concentrated authority forced almost

entirely by legislative inaction. There is reason to believe that it would have been possible three administrations ago to reach a solution of war debts, the greatest present barrier to international trade, had it not been for the inability of congress to foresee and to concur in such a solution.

Another drastic step in concentrated authority, the reorganization of the railway structure, at first glance seems to be a truly emergency measure. When we examine the record, however, we find that for years the carriers themselves have been pleading for permission to develop a reserve which would carry them through possible years of depression; we find further two insistent recommendations in the reports of the Interstate Commerce Commission that Congress either excuse it from the duty of preparing a plan of consolidation or furnish it with sufficient resources to make a real plan. Again, Congress was unable to see what now seems so strikingly clear—that the refusal or inability to perform essential legislative work does not prevent the work from being ultimately done but forces it to be done hastily by concentrated authority and without due deliberation and discussion. So we might pursue our inquiry through almost the entire list of emergency measures which we are now asked to accept without that thorough detailed scrutiny by the legislators which our constitution was intended to provide. The weakening of legislative capacity, the growing demand that more work and more difficult work shall be done, have prevented that orderly, regular and effective transaction of the public business which the spirit of the constitution requires. Have we then an emergency or a penalty for the weak postponement of timely action?

Do the observations which we have considered lend themselves to any tentative conclusions which may be of service in adjusting our government structure to the changes which have occurred?

1. We are now placed before a choice of an attempt to revive the old practice of congressional supremacy or the readjustment of authority between congress and the president

on some new basis. We may reassert the theory of congressional supremacy but if we do it must be with a knowledge that a bloc-infested and bloc-paralyzed congress will again be unable to maintain that steady pace of orderly business which is required, and that other and far more dangerous concentrations of authority in the executive may follow.

2. If we decide to readjust on the basis of a frank recognition of the continued existence of blocs, there is only one way at present known by which this can be done—an open acknowledgment of the greater importance of the executive and its permanent leadership in our federal system. It may seem a paradox to attempt to avoid executive dictation in crises by giving the executive more authority in ordinary times but such is precisely the teaching of our recent experience. The President should be given more of a determinative influence by the constitution itself.

3. The duties of Congress should be shifted from the endless consideration of those matters of minute administrative detail which now absorb almost all its time and should be concentrated upon the full and genuine discussion of real law-making on important matters.

On all three of these points there is abundant evidence available to convince the board of directors and stockholders of a corporation of the necessity for change. May we not hope that the greater openness of men's minds already noted may permit of some similar action in our governmental enterprise?

THE REORGANIZATION OF LOCAL GOVERNMENT

HAROLD W. DODDS

(Read April 22, 1933)

For two generations political scientists and municipal reformers have devoted themselves to the improvement of the structure and operation of local governments. That marked advances have been made in many cities, few informed persons will deny. So far as internal organization and administration, in the narrow sense, is concerned the probable course of progress has been pretty well charted. The difficulty is the practical one of setting the local government ship on this course and holding her to it. Our chief handicaps are bad political habits and unfortunate political traditions.

But the problem is no longer exclusively one of internal operation. The external relations of local governments have suddenly become of prime importance. The right of many of our political units to survive is questioned.

Because of radically changed conditions of transportation and ways of life we are confronted with the need for a complete reëxamination of the geographical size and boundaries of local government units and with the desirability of a new allocation of functions among towns, counties, cities and the state. The situation is as serious with respect to rural and village life as it is for large metropolitan regions. In each case there is involved a number of important readjustments in our local government pattern. And, in the mind of the average American, when one questions the validity of our present pattern he lays a profane hand on the altar of cherished institutions.

It is with the pattern of local government, rather than with questions of municipal politics and administration, that this paper deals.

The Traditional Pattern

Our traditional pattern, hallowed by time and fixed by custom, is, with minor variations from state to state, about as follows:

Our forty-eight states are divided into counties. Counties, in turn, are broken down into towns or townships. In law, counties are merely geographical expressions, involuntary subdivisions of the state, known as quasi-corporations, created as convenient units for executing the policy of the state at large. The township is a geographical expression of even a lower order to meet the simple needs of a microscopic area.

Upon this geographical blue-print is imposed a wide variety of full-fledged, voluntary municipal corporations, variously known as villages, boroughs and cities. Such municipalities possess charters granting wider powers and greater local autonomy than counties and townships enjoy. They provide a broader range of services to their inhabitants and their self-consciousness is, except perhaps in the old South, much more acute.

The pattern grew out of an agricultural civilization, involving an occasional city but for the most part composed of a rural population distributed fairly evenly throughout the state. It was well adapted to the stagecoach and spinning-wheel period. For more than 200 years it has successfully resisted material change, although the conditions which gave it birth no longer obtain.

Is the pattern satisfactory today? The answer is an unqualified No.

Rural and Village Government

Let us consider first the rural and village areas. Although the "delivery" area of local government has been greatly extended, rural localities stolidly refuse to take advantage of the fact. At one time small political units were necessary because the rural community was small, but no longer is this the case. In many states the county today is too small for effective and economical administration; and the township

which de Tocquville so much admired a century ago is now an expensive anachronism.

In New York State we now find, outside New York City, a total of 13,524 local governments of various kinds and degrees, among which are numbered 9,504 school districts.

New Jersey, in addition to 21 counties and 523 school districts, boasts 562 municipalities and townships, exclusive of numerous special districts. While the optimum area for local administration has been increasing, our legislatures have been busy reducing the actual areas by multiplying new units in deference to a false home rule opinion.

The consequences may be summarized as follows:

1. The multiplication of local governments without a clear definition of peculiar services has led to a vertical overlapping and needless duplication of units performing similar or identical functions.

2. Failure to adjust the size of the unit to the service to be performed has resulted in unduly high costs of general administration and exhorbitant overhead expense. Many local units are too small to take advantage of modern large scale methods of operation. For example, many townships and villages are too tiny to make economic use of modern road machinery and methods. Neither can they afford to employ the technical skill necessary to good highway administration.

3. Duplication of functions and high costs of overhead and operation have weakened ability to withstand the economic depression with the consequence that many local governments are facing financial collapse. Their only salvation is through consolidation to seek strength in union.

4. The confused complex of several layers of government, under which many people live, is destructive of democratic responsibility. It is too involved for the average citizen to comprehend; he inevitably surrenders to the professional politician whose job it is to operate the intricate gears.

In general the way out for rural and small town government is simple. Larger units of administration must be de-

veloped. Complete state assumption of certain services now shared by the localities is probably desirable. In North Carolina and Virginia all county roads have been transferred to the state, and to date the results seem satisfactory. For services that are to remain under local auspices county consolidation is necessary to give a broader base of administration. The work of smaller units which have not attained a distinctly urban character must be transferred to the county which will thus be compensated for what it will lose to the state.

The guiding principle should be: Only one unit of local government for a particular service in a given area, the area to be determined by the optimum size for convenient and economical administration. Let the inherent character of the function determine the size of the unit, and not historical and meaningless boundary lines inherited from the stagecoach era. Today it is no more trouble for a farmer to visit a friend in a neighboring county than twenty-five years ago it was to hitch up the bay mare and drive to town for the mail. Recently an official of the Department of Agriculture declared that no rural community of less than 1,000 families can provide an adequate property basis for modern community enterprise. Probably a thousand counties fall below this minimum, not to mention the thousands of smaller villages and townships.

Against the wise policy of reducing the number and increasing the area of our rural and village governments will be arrayed the selfishness of the local politician, the honest pride of citizens in their historic county or village, and the natural fear of bureaucratic abuses of power in the hands of officials removed from the immediate localities which they serve.

Submarginal Territory

A new and special difficulty has been created by the decline of agriculture in the eastern states. Vast cut-over forest areas now harbor but little permanent population. In some cases the only permanent residents are those on government

payrolls. Lands that were once profitable for agriculture have become submarginal as more productive tracts have been opened up in the west.

Yet these submarginal areas are trying to maintain the conventional framework of county and local government on a tax capacity too low to meet expenses without financial aid from outside. These are regions in which tax delinquencies are most disturbing and where per capita costs of local services are highest. The sheer cost of providing roads, schools, health and police protection is too great to be borne locally. The state has had to come to their aid. But state aid cannot be continued indefinitely to sustain a condition patently so uneconomic.

As to the form of local government for such unproductive rural regions, the state of Maine offers a suggestion. In Maine wide forest areas do not attempt the elaborate local government system so common elsewhere. In them the state itself administers all local services and levies and collects the taxes. In this way it has been possible to raise the quality of government and to supply services more economically than do adjoining towns where all the excess ballast of a local organization has been retained. The problem is more complex in backward farm areas not yet abandoned to forests, but economic incapacity to continue along present lines will doubtless force drastic changes.

I have emphasized the situation regarding rural government at some length because city dwellers have both a social and pecuniary interest in it. The nation will suffer if a large proportion of its population is denied access to a decent standard of public services. In many instances these standards are being maintained only through contributions by outside taxpayers in the form of state aid. Once begun, state aid has a habit of increasing rather than decreasing. If city dwellers are contributing to the expenses of rural areas, it is to their interest that their contributions be not frittered away by an antiquated governmental lay-out.

The Metropolitan Region

So much for needful reorganization in rural and village government. We now turn to the problem of the large city. Let us recall that our historic pattern assumed occasional cities throughout the country, isolated from other municipalities, with geographical boundaries completely encompassing an urban area. But our development has not been in accordance with this pattern. The so-called metropolitan region has arisen to disrupt it.

No social or political phenomenon of American life deserves more attention than the startling urban concentration which the last century has brought forth. The large city is the focal point of this concentration. But the political boundaries of the large city no longer define the social or economic community of which the big city is the center. The life of the city radiates into the scores of suburbs which now cluster about it. Together with the city, the suburbs constitute a unit which is a metropolitan region. But this unit is split into scores of political subdivisions, independent of each other, often actually hostile and generally uncooperative.

The census of 1930 enumerates 96 metropolitan regions, each with a central city nucleus of at least 100,000 population. New York, Chicago and Philadelphia are the largest. Together these 96 regions contain 45 per cent of the population of the United States. While the rate of growth of the central cities is declining, the population in the suburbs is increasing by leaps and bounds. Between 1920 and 1930 the population of the 85 metropolitan districts for which data are available increased 25 per cent, compared with an average growth of 10.8 per cent for the area outside these regions.

The 96 districts defined by the 1930 census contain 1,566 incorporated places, not to mention a much larger number of unincorporated political units with independent taxing powers. They cover in whole or in part 250 counties and cut across 23 states. The New York, Chicago and Philadelphia regions each involve three states. The resultant confusion almost

beggars description. Why it is permitted to endure must be difficult for one accustomed to the orderly processes of the physical sciences to understand. A recent Chicago study reports the existence of 1,642 local governments (of all orders and ranks but each with its own taxing power) within the Chicago region, defined as the area within a radius of 50 miles of the intersection of Madison and State Streets. Chicago is a horrible example in a chamber of horrors, but the condition in other centers is scarcely less striking. Politicians have ever been eager to make two governments grow where one grew before.

Yet nothing can be clearer than that such questions as health, water supply, sewerage, police and fire protection, transportation, planning and zoning, and recreation are vital matters to the whole region, and can be met only on a regional scale.

Formerly large cities grew readily by the process of voluntary or forcible annexation of adjacent territory. But today large cities find on their borders other self-conscious municipalities which oppose absorption by imperialistic methods, and prefer, even at great cost, to maintain their political identity. Legislatures are very respectful of the home rule desires of the smaller municipalities, and annexation, voluntary or forcible, is no longer practicable as a method of coördination. Philadelphia has added to her area only one tenth of a square mile since 1854; San Francisco has not enlarged her boundaries since 1856, nor St. Louis since 1876.

In rare cases when some such matter as sewerage or water supply has become acute, steps have been taken to coordinate the area with respect to a particular activity. The method usually has been to set up a special metropolitan district with general authority over a particular matter. Sometimes the authority has been weakened by lack of agreement among the subordinate units whose unanimous consent may be necessary to action. When an *ad hoc* metropolitan body has had sufficient power it has been able to render a service, although

in a limited field. When reliance has been placed upon mutual agreement and coöperation the results have been generally unsatisfactory. This suggests that superior legal force may be necessary to counteract the ruling spirit of extreme individualism possessed by the component parts of the metropolitan region.

The need for a new type of metropolitan authority is imperative. Comprehensive regional surveys such as have recently been completed under private auspices in New York and Philadelphia demonstrate how ineffective an unorganized metropolitan population must be. Carefully drawn plans of regional development remain paper plans because there exists no authority to execute them. Under present laws a single recalcitrant municipality can often obstruct the most essential regional improvement.

The obstacle to regional reorganization is the separatism of the local units. Generally local politicians can be counted in the opposition, and will work to stir up intercommunity antagonisms. Pride in one's town and fear of domination by the big city are honest obstacles of great potency.

Voluntary annexation or complete consolidation being impossible, and state legislatures being unwilling to compel localities to unite, community leaders have turned to our national government for a model, and have proposed that the region be organized on the federation principle. But proposals for federated governments for Pittsburgh and for St. Louis, although moderate in the extreme, have been rejected by the voters. In other centers they have not passed the discussion stage. Important Chicago opinion considers her case almost hopeless in the hands of a downstate legislature, and is beginning to advocate independent statehood for the 5,000,000 inhabitants of the region.

It is an exaggerated and bigoted home rule sentiment that defends the continuance of separate political entities when common interests demand uniform action on common problems. The device of federation is sensible and is probably the only practicable way out. But unfortunately, the suc-

cessful application of this moderate principle demands a broader view and higher statesmanship than has generally been displayed. In due time it will however be clear to even the most exclusive and self-conscious suburbanite that, to protect his pocketbook against excessive governmental costs and his environment against unwelcome encroachments, he will have to join with others in a common government on a metropolitan scale empowered to serve metropolitan needs.

Conclusion

Thus we see that in the fields both of rural or village government and of our large cities we are suffering from a serious lag between social and economic development and political institutions. In each case one of the most difficult problems awaiting solution is chiefly one of geography.

STRUCTURAL IMPROVEMENTS IN THE ADMINISTRATION OF FOREIGN AFFAIRS

DeWITT CLINTON POOLE

(*Read April 22, 1933*)

Though this paper concerns possible structural improvements in the administration of our foreign affairs, I wish to remark at once that structure is of secondary importance in the operation of government. Capable officials can make a passable system of government work well, while good structure is of slight avail with incompetence in office. However, good structure is still important. Capable citizens are attracted to office by the opportunity for efficient service, or repelled by the lack of that opportunity. Structure must be so adjusted as to elicit the best efforts of the officeholder. It must be kept up-to-date in a changing world.

During the 150 years which have elapsed since our present Federal Government was established the world has undergone the swiftest and most complete change of which we have knowledge. Distance has been minimized, time almost annihilated, and the industrial revolution has so interwoven the economic life of nations that we are drawn irresistibly toward an international coöperation which at the end of the 18th century was physically impossible. Concurrently the ideas and workings of democracy have passed beyond the political horizons of the rather conservative gentlemen who framed our Constitution.

Time has more particularly altered the circumstances which led the framers to exclude the House of Representatives from a participation in the making of treaties and to confide the legislative control of that sovereign function to the Senate alone. James Wilson of Pennsylvania, an able lawyer and a clear-sighted democrat, moved in the Constitutional Convention that the House should be coördinated with the

Senate in treaty-making. "As treaties . . . are to have the operation of laws," he declared, "they ought to have the sanction of laws also." He thought that the requirement of secrecy formed the only objection, but this was outweighed in his opinion by the necessity for full legislative sanction. Those opposed to Wilson urged the need of secrecy and dispatch. The House was to number but two thirds of our present Senate, but it was deemed to be too numerous a body to be either secret or swift. Wilson was left in a minority of one. Events have not justified, however, the opposition to his sane proposal. Even at the outset the Senate failed to function as an executive council. The secrecy of its executive sessions has long since become nominal only. The Treaty of Versailles was debated in open session, as indeed it should have been.

Regionalism provided the second principal reason for confiding treaties to the Senate alone and particularly for establishing the two-thirds rule. The Newfoundland fisheries then greatly occupied the mind of New England, and the navigation of the Mississippi the mind of the South. The Senate, where the States were equally represented, seemed the natural guardian of these regional interests. Under the Confederation a bare majority of the States had altered Jay's instructions so as to permit concessions to Spain respecting the navigation of the Mississippi. The requirement of a two thirds vote would forestall the repetition of any such betrayal.

The Senate is still the palladium of regional interests, but do regional interests need a palladium any more, as against the treaty-making power? Senator Johnson of California cried out in 1930 that the Pacific Coast was sacrificed in the London Naval Treaty, but I do not think that he was to be taken very seriously. In the course of a century and a half we have come near to a perfect union. It is difficult to believe that any part of the country is today really in danger of being sold out, as New England might have sold out the South on the question of the navigation of the Mississippi, or

the South might have sold out New England on the question of the Newfoundland fisheries in 1787. I believe that it may fairly be said, with respect to regionalism as with respect to the need for secrecy and dispatch, that the treaty provisions of the Constitution were built upon considerations which have mostly, if not entirely, lost their original force.

Today the leadership which the Constitution gives to the Executive in the conduct of foreign relations is fully accepted and approved, but with the working of the treaty provisions dissatisfaction has long been rife. True, the dissatisfaction is to some extent sporadic, arising from partisan feeling on current issues, but deeper than this there is a conviction among some of the best informed and most experienced that our treaty procedure could be improved by overhauling.

One suggestion is that a simple majority in the Senate might vote concurrence in the ratification of treaties. It has even been suggested that the Senate should be entirely deprived of its participation in the treaty process and that the responsibility should be transferred to the House. However, the most natural, frequent, and I believe the most useful, suggestion is that treaties should be voted by a majority in both Houses of Congress in the same way as any other law. It is my own opinion that, if it is in any way possible to obtain a constitutional amendment, this is the change which should be made.

I would not rest an indictment of the present system upon the formal record of the Senate or its votes upon particular treaties. The formal action of the Senate has been prompt and favorable upon much the greater number of treaties submitted to it; and the wisdom of its course in the celebrated cases of conflict with the Executive remains controversial. It is not on these grounds that I would say that the present system has ceased to be the best-working we could have. Its vice is more subtle.

The crux of the difficulty is found in the two-thirds rule. First, this rule offers inordinate possibilities of obstruction to single senators. who may hold individual and possibly not

fully informed or nationally conceived views on foreign relations. The possibilities of obstruction are increased by the fact that most senators, being good democrats, are interested primarily in domestic affairs. Secondly, since one political party cannot hope to control two thirds of the Senate, the indispensable bridge which party politics builds between the Executive and Congress for the conduct of affairs generally, mostly fails when it comes to treaties. Thirdly, the framers of the Constitution thought that the Senate would act as an executive council, but the Senate is not an executive council and it goes against the fundamental theory of the Constitution that it should be.

Out of these facts has grown a long history of difficulty between the President and the Senate, beginning even with George Washington; in consequence of which the Senate, or a third of the Senate plus one, has been built into a bogy to frighten all those charged with the conduct of our foreign relations. The brooding sense of irrational restraint that settled on the mind of John Hay was in part the fault of a hypersensitive nature, but the more politically inured Secretaries also have been cramped in the pursuit of our international interest by unnecessary apprehensions arising from an anomalous structure of government. The record does not show from what wise measures the President or his Secretary of State has been estopped by perhaps unfounded fear of what a few senators might do, nor is it demonstrable into what brusque and harmful actions the spectre on Capitol Hill has frightened them. In the light of my own reading and my own experience in Washington, I am confident that both misfortunes have frequently befallen.

To replace the present two-thirds rule by a majority vote in both Houses would tend to remove this pathological obstruction to good government, and it would bring our treaty procedure more into conformity with the progress of democracy and the contemporary requirements of treaty-making. The existing treaty arrangement was conceived by the framers of the Constitution in an anti-democratic sense. Yet in no

realm has the advance of democracy, especially during the last decade, been so swift and changeful as in that of diplomacy. For the first time modern democracies are giving direct attention to their foreign relations, and open diplomacy is established. The essence of open diplomacy is the widest possible public discussion of the concrete results of diplomatic negotiations, especially of the national commitments embodied in treaties.

It is also important, from the point of view of democracy, that every completed treaty should register a fully conscious national obligation. Experience with the Panama Canal tolls has shown how difficult it may be to hold a popular government to antecedent obligations. You will recall that by the Hay-Pauncefote Treaty of 1901 we agreed with Great Britain that the Canal should be open to all nations without discrimination in respect of the conditions or charges of traffic. Despite this treaty obligation the Panama Canal Act passed by Congress in 1912 provided that no tolls should be levied on vessels engaged in the coastwise trade of the United States. It required President Wilson's utmost effort at the height of his prestige and three months of acrimonious Congressional debate to obtain the passage through Congress of the amendment which finally vindicated the honor of the United States. In 1881 we concluded a treaty with China by which a certain amount of Chinese immigration was permitted. Though this treaty was duly ratified and proclaimed, the Congress subsequently passed a law totally excluding the Chinese, and China had grounds for international protest. It would go some way to increase the consistency of our foreign policy and fortify our international good faith, if the popular branch of Congress were also formally committed to every obligation which we undertake by treaty.

Furthermore, it becomes increasingly desirable that the acceptance of a treaty should carry with it by the same act every needed statutory result. In the newer democracies of Europe the parliament records its approval of a treaty by

normal legislative enactment. At one stroke the Executive may be authorized to ratify the treaty and the treaty acquire the force and effect of a domestic law. The American Constitution declares treaties to be part of the supreme law of the land, but a considerable number of our treaties are still not self-executing. This is conspicuously the case when fiscal measures are involved. In fact, the House already shares by its fiscal prerogative, in the treaty-making power. President Roosevelt has just applied to the whole Congress for statutory authority to conclude reciprocal tariff agreements. The President and the Senate contracted with Russia for the purchase of Alaska in 1867, but more than a year elapsed, and we had already taken jurisdiction over the new territory, before the House could be induced to vote the agreed purchase money. If ratification of a treaty were advised through the enactment of a law by the two Houses in the normal manner, delays and uncertainties would be removed.

Such a change is especially to be recommended on account of the increasing volume of international law-making on subjects which were until recently of wholly domestic concern. By means of multilateral treaties the principal countries have begun a code of international legislation which takes on more and more the extent and character of the *corpus juris* of a single nation. We signed the first of these treaties in 1875. We adhered to seven more in the decade of the '80s, ten in the decade of the '90s, and more than twenty in the last ten years. These treaties relate to administration and police in such matters as patents and trademarks, weights and measures, bills of lading, submarine cables, aërial navigation, radio-telegraph, time, safety at sea, sanitation, liquor traffic, white slavery, naturalization, and the traffic in arms. Such were not the historical subjects of treaties in the days when traditional treaty procedures took form. They are matters of domestic legislation which modern conditions have carried beyond national frontiers.

That a harmful tradition of conflict has been built up between the Senate and the Executive largely on the ground

of the two-thirds rule; that the progress of democracy demands the largest possible forum of discussion, and the widest participation in obligation, when treaties are made; that there would be practical advantages in the assimilation of the treaty-making to the law-making process—these reasons call for an end of the peculiar legislative regime created historically for the making of treaties and its replacement by the normal legislative process. But I am painfully aware that such arguments, though persuasive enough for me, are not of a kind to meet wide popular understanding and response. No specific interests in the country are so touched as to be ready for the wide, sustained effort which can alone bring about a change in our fundamental law. I think that those of us who are convinced should advocate the change persistently, for the mere advocacy may have a salutary effect at Washington; but at the same time we shall have to look about for other and easier methods to improve the structure for the administration of our foreign affairs.

Professor R. J. Dangerfield, in a valuable study recently published under the title *In Defense of the Senate*, proposes a Foreign Relations Cabinet which would include the Secretary of State and one or two higher officials of the State Department and the chairmen and ranking minority members of the Senate Committee on Foreign Relations and the House Committee on Foreign Affairs. This seems to me an attempt to start parliamentary government in a country having an entirely different sort of constitution, and I do not believe that such a body will ever come to life.

I believe, however, that there are possibilities in the enlargement of the structure of the State Department which would benefit generally the conduct of our foreign relations and facilitate coöperation between the executive and legislative branches. The main structure of the State Department resembles broadly that of the other principal foreign offices of the world, being determined by the practical requirements of the work to be done. A new general framework is not required or desirable or feasible. What the Department

needs mostly is ample, high-grade personnel. In one direction, however, the present structure can be usefully developed.

Next to good internal working, the most vital need of the foreign office of a democracy such as ours is smooth and effective contact with the legislative branch of government, with the press, and with the general public. In the parliamentary democracies of Europe contact with the legislature is provided by the parliamentary structure of the government—the British Foreign Office has its Parliamentary Under Secretary. Much attention is given in the United States, as well as in Europe, to relations with the press. This relationship has been well worked out at Washington.

The present deficiency of our State Department has to do with informal relations with Congress and contact with the general public. Naturally the relationship with Congress varies according to the personality and previous experience of the man who is for the time being Secretary of State. However, the Secretary cannot himself be the sole nexus with Congress. The business of the Department is too voluminous and varied and time is too short.

The Department of State needs to be equipped to receive in the most suitable manner the casual calls of members of Congress and to fulfill their various requests, and increasingly it needs to know—and by "it" I mean the twelve or fifteen principal officers of the Department—how the state of opinion in Congress moves respecting the foreign questions of the day. In the same way the Department needs to be in close feeling with the movements of public opinion generally.

There ought to be created in the Department a special agency of outside contact which, while closely coördinated with the existing offices, should nevertheless be free from the administration of the Department's central business. A principal reason for the present deficiency in liaison is the tremendous pressure of immediate questions, which bear so relentlessly upon the Secretary, the Under Secretary, the Assistant Secretaries, and the division chiefs. The need is for some individual in the Department, or preferably a group

of individuals, who are informed of current business but are not immersed in the dispatch of that business and so have time for talk and thought and outside circulation.

On another occasion [1] I have suggested the incorporation in the Department of an advisory or study board. Such an organ would develop touch with Congress, the other executive departments, and the general public, through the active study of specific foreign problems, including problems which are not at the moment under negotiation or adjustment. It would be a planning board distantly comparable to the so-called planning divisions of the War and Navy Departments. It would submit information and advice to the Secretary on his request. It would remain entirely subordinate to the Secretary, and of course its advice would be confidential and have no validity except so far as the Secretary might choose to accept it.

A board of this kind should not include members of Congress. Members of Congress are too much occupied with their own duties. They have their own constitutional responsibilities. As I have suggested above in connection with Professor Dangerfield's proposal, the formal participation of members of Congress would tend to counter the constitutional theory of the separation of powers. Let there be a maximum of informal contact and coöperation with members of Congress, but that coöperation cannot be institutionalized.

To an advisory board of this kind I perceive an alternative which is more feasible and less adequate. This is to assign one of the Assistant Secretaries of State exclusively to the work which I have outlined. He would supervise the existing Division of Current Information, or press bureau, and perhaps the Historical Adviser's Office, which keeps the archives and controls public access to them. He would have to command the Secretary's complete confidence and work in understanding sympathy with his aims. He would have to be

[1] *Cooperation abroad through organization at home*, in *Annals* of the Am. Acad. Pol. & Soc. Sci., July, 1931. See also *Strongest possible State Department best assurance of peace*, in *Am. Foreign Service Journal*, Jan., 1933.

persona grata at the White House and on Capitol Hill. Congressmen having business with the Department, and the general public, would normally go to him in the first instance. Something of the kind has been tried from time to time, but I do not think that it has ever been as fully developed as it might usefully be. Such an officer cannot be wholly passive; he must reach out, tactfully.

These are illustrative suggestions. In any change that is made somewhat must depend upon the personal inclinations and methods of the Secretary for the time being. The State Department is a small organization and its structure has to be kept elastic and adaptable. I wish on this occasion only to emphasize the need for an enlargement of some kind which would create an active two-way contact between the State Department and the individual members of Congress and the public. The atmosphere of the offices where the character and tone of our foreign relations are largely determined needs to be ventilated both in and out. The public must have access to the Department and the Department to the public, if we are to have the best development of our inevitably democratic diplomacy.

The attainment of a wisely conceived and skilfully executed foreign policy depends first of all upon the wisdom, efficiency and character of the men whom we place in office. The structure of government can, however, help or hinder coöperation among these officers and elicit or dampen their best thought and effort. I believe that a change in the constitutional procedure on treaties such as I have suggested above would remove some serious existing difficulties. Though hard to bring about, I have faith that some day this amendment will come. Meanwhile structural enlargement of the State Department in the direction which I have indicated would have a beneficial effect upon the general conduct of our foreign relations, and would help to remove the difficulties which have arisen under our extraordinary system of treaty-making.

RECENT DEVELOPMENT OF THE AMENDING POWER AS APPLIED TO THE FEDERAL CONSTITUTION

HERMAN V. AMES

(*Read April 22, 1933*)

In a paper the speaker had the honor to present to this Society in 1924, on the Amending Provision of the Federal Constitution in Practice,[1] he reviewed the efforts to amend the Constitution during the period of over a century and a third. It was shown that in that period more than thirty-five hundred amendments had been proposed in Congress, but that in the first one hundred and twenty years only fifteen amendments had been secured. With the ratification of the fifteenth amendment in 1870 there ensued a period of forty years without any additional amendments. Beginning with 1909 four amendments were effected in a little more than a decade. The paper also reviewed various criticisms of the amending provision and efforts to change them with a view, for the most part, to render the methods easier, and especially in the later years to insure greater popular control over their ratification. The survey closed with a brief discussion of the more important decisions of the Supreme Court of the United States, during the years 1920–1924, relating to several questions of procedure followed in the submission and ratification of amendments. These were the result of several attempts to have the eighteenth amendment declared void for alleged irregularities in some phase of the process which had been followed. All these efforts, however, were unsuccessful, but some of the rulings of the Court have had important bearing on recent procedure.

The present paper is offered as a supplement to the former one, for in the nine years that have since elapsed, increased activity has been manifested in the effort to effect amend-

[1] *Proceedings of the American Philosophical Society*, Vol. LXIII, No. 1, pp. 62–75.

ments, and three additional proposed amendments have been submitted by Congress to the states for ratification.

As illustrative of the unusual number of proposals to amend the Constitution introduced in Congress in these years, the figures for the first session of the 73d Congress, may be cited. It extended from December 7, 1931 to July 16, 1932, or a little more than seven months.[2] In this period one hundred and thirty-five amendments were proposed on some twenty-three different subjects. The effort to repeal the eighteenth amendment found expression in fifty-nine different resolutions and eight proposals to change the method of amendment itself, some of which had the same object in view. There is little question that the shock suffered by the advocates of local autonomy in consequence of the adoption of the Prohibition Amendment has led them to advocate greater popular control in ratification.

The first of the three amendments submitted by Congress to the states for ratification during the nine years period was the Child Labor Amendment. This proposed to confer on Congress "the power to limit, regulate and prohibit the labor of persons under eighteen years of age." It was passed June 3, 1924,[3] after the Supreme Court had declared the Federal Child Labor law of February 19, 1924, unconstitutional. This was an effort to protect minors in those states that had not adopted effective laws on this subject. Unexpected opposition to this amendment developed. It was objected to as an attempt to transfer to the jurisdiction of the Federal Government the police power of the States and was the manifestation of "a dangerous tendency toward centralized bureaucracy." In consequence twenty-six states rejected it and after seven years only six states had approved it, so that the probability of its ratification appeared dubious. Recently, however, there has been renewed interest in this proposal, due in part to the active support of the American Federation of Labor, and to the disclosures made by Secretary

[2] Congressional Record, 73d Congress, 1st sess.

[3] Cong. Rec., Vol. 65, pt. 7, p. 10303.

Perkins, of the Federal Labor department, of sweatshop conditions in connection with the employment of children. As a result four states recently have acted favorably, and ratification resolutions are pending in eleven additional state legislatures. As no time limit was fixed by Congress within which the amendment must be ratified as was true of the eighteenth amendment and some other recent proposals, and as there is no provision prohibiting a state legislature reconsidering its previous disapproval, while the amendment is still pending, it is not impossible that this proposal may yet be ratified by the requisite three fourths of the state legislatures. It is possible that in the case this amendment should be ratified after a considerably longer period of time has elapsed that the Supreme Court might rule against it on the ground that it had not been ratified within the "reasonable time" limit as defined in the case of Dillon *vs.* Gloss.

The second amendment proposed by Congress in recent years was submitted March 2, 1932. It is popularly known as the "Norris Lame Duck Amendment."[4] It had been advocated for several years by Senator Norris and had passed the Senate seven times, but previous to this past year, it had failed in the House due primarily to the opposition of the late Speaker Longworth. Last spring the two houses finally reached an agreement, and it was passed by very large majorities both in the Senate and House. The amendment proposed to change the date of the meeting of Congress to January 3d of each year, and of the inauguration of President and Vice-President to the 20th of January following the election. The amendment provided further that, if adopted, the terms of Senators and Representatives shall end on the third of January, and of President and Vice-President on the twentieth of January of the year in which their terms nominally would have ended. This change will have the effect of abolishing the short session of Congress, and hence the popular name given to the amendment. The proposal proved to be popular and on the ratification of thirty-six

[4] Cong. Rec. 72d Cong., 1st session, Pt. V, pp. 5026–5027 for text. Also pp. 5148, 5153.

states, January 23, 1933 became the twentieth amendment to the Constitution.[5] The amendment goes into effect on October 15 of the present year. A correspondent of *The New York Tribune* questions whether this amendment can be put into operation in the case of the present President and Vice-President owing to its not having been ratified [6] until after their election and because it does not go into effect until two hundred and twenty-five days after they have exercised the powers of these offices and for other technical reasons conflicting with provisions of the Constitution.

The third amendment providing for the repeal of the eighteenth amendment was proposed by Congress on February 20, 1933,[7] having passed the Senate by a vote of 63 to 23 and the House of Representatives by a vote of 289 to 121. The campaign for the repeal of the Prohibition amendment began almost as soon as the amendment had been adopted, and has gathered strength in recent months. Apart from the question at issue, interest centers in the provision for the ratification of the amendment, as Congress for the first time in our history chose the alternative method provided for in the Amending article, namely, submission to conventions in the states.

A review of the steps which led to the drafting of the Amending Provision in its final form by the Federal Convention of 1787 seems to throw some light on the intent of the framers. Although the Convention, early in its session, agreed to the resolution "that provisions ought to be made for the amendment of the articles of union whensoever it shall seem necessary," [8] the first definite proposal of the method to be followed was presented in the report of the Committee on Detail, August 6. This provided that "On application of two thirds of the States in the Union for an amendment of this Constitution the Legislature of the United States shall call a Convention for that purpose." [9] It was not until

[5] Cong. Digest, Feb. 1933. p. 60.
[6] March 26, 1933.
[7] Cong. Rec., 72d Cong., 2 sess., p. 4550 for text.
[8] Farrand, *Records of the Federal Convention*, Vol. I, p. 227.
[9] Farrand, *Records of the Federal Convention*, Vol. II, p. 188.

September 10, that this, the 19th article of the report came up for discussion. This proposal was not satisfactory to Alexander Hamilton, among others. He was of the opinion that the mode proposed "for supplying defects which will probably appear in the new system, was not adequate." "The State Legislatures," he said, "will not apply for alterations but with a view to increase their own powers. The National Legislature will be the first to perceive and will be most sensible to the necessity of amendments, and ought also to be empowered, whenever two thirds of each branch should concur to call a convention." [10] James Madison likewise called attention "to the vagueness of the terms 'call a convention for the purpose,' as sufficient reason for reconsidering the article. How was a Convention to be formed? by what rule decide? what was the force of its acts?" [11] In other words, what was to be the extent of the power of the legislatures and the convention respectively? The force of Hamilton and Madison's arguments led to the reconsideration of the article. Mr. Madison then proposed a new draft, which he submitted. This embodied Hamilton's suggestion that Congress might propose amendments "whenever two thirds of both houses should deem necessary," as well as on application of "two thirds of the legislatures of the several states," and added for the first time the proposal that such amendments shall be valid "when the same shall have been ratified by three fourths at least of the legislatures of the several states, or by conventions in three fourths thereof, as one or the other mode of ratification may be proposed by the legislature of the United States." [12] This omitted the phrase "call a convention for the purpose," of proposing amendments, the vagueness of which he had criticized.

Thus the contemporary records show that the first part of the new draft was due to Hamilton's suggestion and the second part in regard to ratification to Madison. The debates do not reveal the reasons that actuated Madison in

[10] Ibid., Vol II, p. 558.
[11] Ibid.
[12] Farrand, *Records of the Federal Convention*, Vol. II, p. 559.

proposing ratification by conventions in the states, as an alternative method to ratification by state legislatures, but it would seem reasonable to infer that it was due to the same consideration that led the Convention to submit the draft of the Constitution for ratification to conventions in the states rather than by the Legislatures. This was in harmony with the prevailing theory of the age, namely, that the sovereign people spoke directly through a convention elected for a specific purpose. Both Hamilton and Madison gave expression to this thought in *The Federalist*. Thus Hamilton wrote, "the fabric of American empire ought to rest on the solid basis of the consent of the people—that pure, original fountain of all legitimate authority." [13] Madison also declared that "the express authority of the people alone could give due validity to the Constitution." [14]

Shortly before the Convention had completed its work, on September 15, the Amending provision, Article V, of the report of the Committee on Style, came up for final adoption. With some slight changes in the phraseology its main features were similar to the form in which Madison had proposed it and the Convention accepted it. Some of the members of the Convention objected to the omission of the clause requiring Congress to call a convention "to propose amendments on the demands of two thirds of the states." Both Messrs. Morris and Gerry moved to restore the omitted phrase. In discussing this proposal Madison declared he "did not see why Congress would not be as much bound to propose amendments applied for by two thirds of the states as to call a convention on the like application. He saw no objection, however, against providing for a convention for the purpose of amendments, except only that difficulties might arise as to the form, the quorum, etc., which in constitutional regulations ought to be as much as possible avoided." [15] This amendment to Article V was accepted by general consent, the only other changes were, excepting from amendments the

[13] *The Federalist*, No. 22.
[14] *The Federalist*, No. 42.
[15] Farrand, Vol. II, pp. 629-630.

two well-known provisions of the constitution. In view of Madison's reference to the difficulties that might arise in regard to "constitutional regulations," applying to a convention to propose amendments, it is rather remarkable that neither he nor any other member of the Convention, as far as the Records show, raised a similar query in regard to regulating the details of the procedure of ratifying conventions in the states. Is it not reasonable to conclude, in the absence of such considerations, that the framers expected that the State Legislatures would make all necessary provisions relative to such matters, just as they expected the Legislatures of the respective states to attend to the details of the state conventions to which they desired the draft of the Constitution to be submitted?

As already stated, the recent proposal to repeal the eighteenth amendment is the first instance in one hundred forty-four years that Congress has resorted to the alternative method of ratification by conventions. However there have been a few attempts made by Legislatures of States and individual members of Congress to secure the calling by Congress of a convention to propose amendments. The most significant of these were just before and during the Civil War, but these as well as a few later proposals were unsuccessful.[16] More recently some efforts to change the method of amendment itself, to render it easier to initiate amendments, have been attempted.[17] These proposed either the reduction of the number of State Legislatures required to demand a Convention or substituted the requirement for the submission of an amendment by Congress, on the demand of a certain proportion of the voters of the states.[18] Similarly there have been several attempts to submit for ratification certain proposed amendments to conventions in the states. This was true at the time the resolutions, which subsequently became

[16] Ames, Herman V., *Proposed Amendments to the Constitution of the United States During the First Century of its History*, pp. 281–286. Mussmanno, M. A., Proposed Amendment to the Constitution, 70th Congress, 2d Session, House Documents, No. 551, pp. 189–191.

[17] Mussmanno, pp. 189–193.

[18] Ibid., 194–198.

the thirteenth and fifteenth amendments, were under consideration. These efforts were made by those who were opposed to the ratification of these amendments and were urged in the hope that submission to conventions would be more likely to accomplish their defeat.[19]

In opposition to these proposals it was urged that such a method would be dilatory and expensive; that the speediest and simplest way to effect ratification was through the State Legislatures, as these did not have to be specially called and no additional expense was incurred by this method.

Among the recent suggested changes in the amending provision of the Constitution, have been ratification by some form of referendum, either directly or indirectly.[20] This has been especially advocated by those who championed the repeal of the eighteenth amendment. They believe that popular participation in ratification will increase the chances for its repeal.[21] Thus Senator Edwards of New Jersey, as well as others, have proposed on several occasions in the past six years the submission of the repeal of the eighteenth amendment to conventions in the States, the conventions to be held within a certain limited period.[22]

The right of Congress to fix a period within which the amendment submitted must be acted upon has been exercised by Congress, first in the case of the eighteenth amendment when the period was limited to seven years. This was challenged in the case of Dillon *vs.* Gloss in 1921, but the Supreme Court held that this provision was constitutional, stating that this was "a matter of detail which Congress may determine as incident to its power to designate the mode of ratification," and that seven years was "a reasonable period."[23] This precedent has been followed by Congress in the recently adopted twentieth amendment as well as in the proposed repeal of the eighteenth amendment submitted only

[19] Ames, pp. 286, 287.
[20] Mussmanno, pp. 199-204.
[21] Ibid., 237-241.
[22] Ibid., pp. 240-241.
[23] 256 U. S. 368.

two months ago. In each of these the same period of time, seven years, was designated.

Since our previous resume of the decision of the Supreme Court relative to the eighteenth amendment, there had been one further important decision on a question of procedure that merits attention. In 1930 Mr. Justice Clark of the Federal Circuit Court held in the case of Sprague *vs.* the United States that the eighteenth amendment had not been constitutionally ratified inasmuch as the very nature of the proposal took away power from the states and their citizens; the people of the states should have been given an opportunity to pass upon it through conventions. Congress had, therefore, grossly erred in submitting the amendment to the Legislatures of the States. Notwithstanding the favorable action of the State Legislatures by the required majority, the amendment was not properly a part of the Constitution.[24] The Supreme Court, however, in 1931, emphatically rejected this contention, stating that "this Court has repeatedly and consistently declared that the choice of mode rests solely in the discretion of Congress." "If the framers of the instrument had any thought that amendments differing in purpose should be ratified in different ways, nothing would have been simpler than to phrase Article V so as to exclude implication or speculation." [25] Partly as a result of popular discussion of the question raised by the Sprague case, but still more because of the growing belief of the proponents of the repeal of the eighteenth amendment, that the chances for success were greater through the submission of such a proposal to conventions, specially elected to pass solely on this issue, than through State Legislatures chosen on a variety of issues, both the Democratic and Republican National Conventions in 1932 adopted planks in their respective platforms calling for submission of such an amendment to Conventions.

In conformity with these declarations, the recent Congress submitted the proposed Amendment to repeal the prohibition amendment to conventions in the States. Even before this

[24] U. S. *vs.* Sprague, 44 Fed. (2d), 982, 983.
[25] U. S. *vs.* Sprague, 282, U. S., 716-734.

action had been taken by both houses of Congress, some novel questions were raised in regard to the extent of the powers of Congress in prescribing the details of the election and procedure of the state conventions. Two opposite views soon found expression. The one in favor of the full power of Congress to prescribe the same which view was very ably presented in a Brief by the Hon. A. Mitchell Palmer, former Attorney-General. The other, by the Hon. James M. Beck, a member of the House of Representatives and a former Solicitor-General, challenged this contention in a speech in the House. Each answered the original arguments of his opponent in a supplementary Brief or speech.[26]

We can do little more than present a short summary of the position of each without their supporting arguments.

Mr. Palmer contended that Congress has the unrestricted choice of two modes of ratification. The two modes are entirely separate and distinct. The selection of one is the rejection of the other. The courts have held that ratification of an amendment is "a Federal function";[27] that being the case "the State cannot act in creating or maintaining the Convention or in determining how it shall operate." "This leaves an inevitable dilemma—either Congress has the necessary power or no one has it." "Congress can make the necessary regulation as a normal part of its task of procuring the decision of the question of ratification by Convention." . . . "While no express power is delegated to the Congress to call Conventions or provide for the assembly thereof, it has always been recognized that all powers necessary and proper for the execution of express powers are implied." . . . The Supreme Court "has applied this principle to Article V by holding that the Congress as an incident to its power to designate the mode of ratification, has the implied power to fix a reasonable period within which the legislature must act." "If Congress has the power to prescribe the time

[26] Brief submitted by A. Mitchell Palmer, Nov. 30, 1932; supplemental Brief, Jan. 2, 1933 (Washington, D. C.). Speech of James M. Beck in the House of Representatives, Dec. 7, 1932 (Washington, 1932). Reply to supplemental Brief of A. Mitchell Palmer, Jan 24, 1933 (Washington, 1933).

[27] Hawke *vs.* Smith, 253 U. S. 350 Leser *vs.* Garnett, 258, U. S. 137.

within which State Legislatures must act on a proposed amendment, can there be any doubt that it has similar powers to prescribe the time within which Conventions in the several states must act . . . whenever the Congress . . . selects that mode of ratification? And subject to the limitation that such implied powers must be exercized 'within reasonable limits,' it seems clear that the Congress has power to prescribe the time when and the manner in which such Conventions shall be chosen and shall function." . . .

He argued that if Congress permit the State Legislatures to determine the details for the creation and conduct of the Conventions in the states, it will ignore and fail to exercise the power which the people in convention delegated to Congress. By such action the Congress would employ both methods of ratification—it would use both the legislatures of, and conventions in, the states. It is without power to do this, for the Constitution restricts the Congress to "one or the other mode."

It will thus be seen that Mr. Palmer argues in favor of a broad construction of the implied powers of Congress, while Mr. Beck, on the contrary, presented a direct and literal interpretation of the text of the amending provision of the Constitution. The latter held that "the power of Congress is limited by the text of the instrument to the method of ratification—whether by legislatures or conventions—and the time within which such ratifications must be made" and contended that there is no textual or even historical justification of "the Palmer theory." Mr. Beck laid great weight on the tenth amendment by which "the powers not delegated to the United States by the Constitution nor prohibited by it to the states are reserved to the states respectively or to the people" and held that "the theory of powers based upon a *casus omissus* is answered by the tenth amendment." We agree with Mr. Beck that if it had been intended that Congress having selected the mode of ratification, could thereupon supervise the ratification by the states, whether by legislatures or conventions, presumably the Constitution would have said so.

In harmony with Mr. Palmer's argument, on Feb. 20, 1933, the same day that the House of Representatives approved of the Senate resolution submitting the repeal of the eighteenth amendment to conventions in the states, Mr. La Guardia introduced a bill [28] providing for the election of delegates to a convention in each state—fixing the date of the election (May 16, 1933) the number of delegates, and all the details of the election proceedings and for the convening of the delegates chosen in Convention at the State Capital not less than thirty days nor more than forty-five days after the election; the proposed amendment was to be transmitted to each State Convention by the Secretary of State and the presiding officer of each of the Conventions was to report its action to the Secretary of the State. Finally the bill provides for an appropriation of $7,500,000 for carrying out its provisions of the law, including the expense of the election, the mileage and subsistence of the delegates to the Convention but no compensation. This was not acted upon beyond reference to the Judiciary Committee. Desirable as uniformity in the methods of choice and character of the conventions might be, members of Congress apparently were apprehensive that constitutional objection might intervene to jeopardize the validity of the ratification of the amendment. According to press reports the late Senator Walsh, who was expected to be the new Attorney-General, gave it as his opinion that such a procedure was questionable, and it was decided to send the proposed amendment to the states, leaving it to the respective State Legislatures to take such action as they might choose relative to calling conventions, as well as the other details of the election of the delegates. Already twenty-nine State Legislatures have taken action, and most of the others are expected to do so in the next few weeks. Conventions have been held and favorable action taken on the amendment in Michigan and Wisconsin. As was anticipated there has been considerable variety in the action of the

[28] Cong. Rec., 72d Cong., 2d sess., p. 4584. Text not given in Record, but in printed copy of bill, No. H. R. 14728.

State Legislatures that already have passed on the subject, in regard to the size of the convention, the distribution of the delegates, whether they shall be chosen by general ticket in the state at large, or by districts, or by a combination of both. From the action already taken it would seem that the conventions will not be deliberative in character, but simply will serve to register the votes of the delegates chosen, who are to be listed on the ballots as in favor or opposed to the adoption of the amendment. In other words, while observing the provisions of the Constitution for ratification by conventions in the states, the procedure will be rather in the nature of a referendum.

A new and unexpected factor has been raised by the attempt of the Governors of two states, viz. of Alabama and Pennsylvania, to defeat the calling of the convention, as certain provisions of the bills for that purpose were objected to by Governor Miller and Governor Pinchot respectively. In the former case the bill was promptly passed over the veto, in the latter it has been temporarily successful pending the passage of a new bill. In the past when the Legislatures have acted on constitutional amendments it has acted in "its federal function," and only one instance has been noted where a Governor has attempted to exercise a veto. The necessity of the Legislature passing a measure for calling the convention however has offered the opportunity for the intervention of the Governor by the use of his veto.

Whether the repeal of the Eighteenth Amendment through conventions will prove easier than by legislative action, as anticipated by its advocates, remains to be seen. The opponents of its ratification are bending all their efforts to obtain its rejection in at least thirteen states.

In conclusion it may be noted that in no previous period since the adoption of the first ten amendments has there been so great activity in amending the constitution as in recent times. In contrast with two earlier periods, the one of sixty years before the Civil War, and the other of forty years following the adoption of the reconstruction amendments, in

neither of which were any amendments secured; the fact should be noted that in the past twenty-four years, seven amendments have been submitted by Congress and already five of these have been ratified. It has been demonstrated that "the cumbrous machinery of Article V," as it was once described by the late Woodrow Wilson, can be made to work when public opinion is sufficiently aroused.

MEMORIAL OF

RICHARD ALEXANDER FULLERTON PENROSE, JR.

December 17, 1863—July 31, 1931

A Tribute to His Life and Achievements

WALDEMAR LINDGREN

All too early, before his sixty-eighth birthday the life of Penrose came to an end. In spite of evidence of his declining physical health his friends had hoped he might be spared for another decade of useful life. I have been asked to present his life history to the American Philosophical Society. Many could do it better, but none could approach the subject with more admiration for or appreciation of the character and work of Penrose. I have often thought that this memorial could be aptly condensed into four characteristic words: Richard Penrose: Gentleman, scholar, engineer, benefactor.

The history of Penrose's family reaches back for many hundreds of years. As the name indicates, it had its origin in Cornwall, and his ancestry, which can be traced back to the sixteenth century and probably even farther, included many prominent men. As Mr. J. Stanley Brown says,[1] the name is to be found for hundreds of years connected with such activities in its homeland as called for vision, courage, and perseverance. The historical records of Great Britain indicate conspicuousness in law, in medicine, in diplomacy, in the church, in politics, in education, in industry and commerce, and in battle by land and sea.

One of his ancestors, Bartholomew Penrose, emigrated to America in 1700, and settled in Philadelphia where he engaged in shipbuilding and commerce. During the many intervening years since then, we find "the Penrose descendants allying

[1] "Memorial of Richard A. F. Penrose, Jr.," *Bull. Geol. Soc. Am.*, 43, 68–69, 1932.

themselves, by marriage, with such families as the Drexels, Biddles, and Waynes, engaging in every variety of activity in this new land of promise." The family history in America includes many brilliant and successful lawyers and professional men.

R. A. F. Penrose, Jr., was of the seventh generation from Bartholomew Penrose. His father, Dr. Richard Alexander Fullerton Penrose, for whom he was named, became a widely known surgeon, and was for many years identified with the University of Pennsylvania. He married in 1858 Sarah Hannah Boies of Maryland, who became the mother of seven sons, among whom were Boies Penrose, well known in the political history of Pennsylvania; and Spencer Penrose, financier and mining man, whose home is in Colorado Springs, and who is now the only surviving member of the family.

R. A. F. Penrose, Jr., was born in 1863 during the troubled times of the Civil War. Conforming to the family traditions, he received a careful and well-balanced education. I am sure that many of his characteristics had their origin in his early training by his parents, and the consciousness of his long family history was no doubt also an important factor in his life.

In 1880 at the age of seventeen years, he passed the final entrance examinations for Harvard University and received his A.B. degree in 1884. Two of his brothers were studying at the same time and graduated from Harvard in 1881. In 1886 he had completed his studies and in June of that year he received the degrees of A.M. and Ph.D. It is stated that he was the first to take his degree in Geology at Harvard, the subject of his thesis being phosphate deposits. Much information is not available about his life at Harvard except that he apparently devoted himself most industriously to his studies. In the latter part of his college career he took more or less interest in athletics, especially in rowing. Already during his college years he took important trips abroad, particularly to Europe, and to various parts of Quebec. At that time he became interested in phosphate deposits, the

subject of his thesis. He visited most of the Quebec and Ontario phosphate mines and also managed one apatite mine in the valley of the Aux Lièvres River, Quebec. This was apparently his first experience in mining. During his college days he found a warm friend in Professor N. S. Shaler, the well known teacher of geology, who no doubt influenced him very materially in the choice of his life's work. Later the same year, 1886, he visited the phosphate deposits in the southern states, particularly in Sough Carolina and Florida. His thesis on phosphate deposits proved to be so valuable that it was published by the U. S. Geological Survey as Bulletin 46, "Nature and Origin of Deposits of Phosphate Lime, with an Introduction by N. S. Shaler," Washington, 1888, 143 pp.

In 1888, he was appointed Geologist in Charge of the eastern section of Texas, under E. T. Dumble, who had just organized a geological survey of that state; in this occupation he was busy for the next two years. His work was mainly connected with the study of the Tertiary formations which cover a strip of about 500 miles parallel to the coast of the Gulf of Mexico. His work was of great importance as a reconnaissance, and outlined the main features of the Tertiary rocks in the Rio Grande region. The results of his work in Texas appeared in the First Annual Report of the Geological Survey of Texas, in 1889. Likewise, he made a report on the iron ores of East Texas, which are derived from glauconite sediments. In the summer of 1890 he left reluctantly the Geological Survey of Texas to join the Geological Survey of Arkansas, under Dr. J. C. Branner, to examine and make a report on the geological relations of the manganese and iron deposits. The two years which Penrose spent in Arkansas, of which he says the redeeming feature was his association with Dr. Branner, were occupied in studies of the deposits referred to in all portions of the state and involved a difficult task of thousands of miles of travel and many hardships. While it is true that the work did not disclose any large resources of iron and manganese in Arkansas, it proved the foundation of important papers on the manganese deposits published by the

Geological Survey of Arkansas in 1890, as Volume 1, 642 pp., and other papers on allied subjects in the *Engineering and Mining Journal*, the *Bulletin of the Geological Society of America*, and in other places. A report on the iron deposits of Arkansas was published by the Geological State Survey in Volume 1, 1892, 143 pp., and for several years afterwards he contributed manganese statistics to the annual publication of the *Mineral Industry* edited by R. P. Rothwell. His connection with the Geological Survey of Arkansas ended in 1893.

In 1892, he was appointed Associate Professor of Economic Geology at the University of Chicago, and Professor in 1895. His academic activity practically ceased some years later, but he remained a member of the staff to 1911. In 1893, he lectured at Stanford University. An interesting article dealing with his academic life at Chicago and his association with Chamberlin and Salisbury was published in the *Journal of Geology* in 1929, entitled, "The Early Days of the Department of Geology at the Chicago University."

His next undertaking led to the survey of the newly discovered district of Cripple Creek in coöperation with Dr. Whitman Cross. He was appointed as Geologist of the U. S. Geological Survey in 1894, and remained in that organization connected with this work until 1896. The report on the Cripple Creek district, a most important contribution to mining geology, was published in the Sixteenth Annual Report of the U. S. Geological Survey. As a result of his extensive investigations in the superficial alteration of ore deposits he published another valuable paper in the *Journal of Geology* in 1894, which was republished in full in 1912 by the American Institute of Mining Engineers as a chapter in the *Emmons* Memorial Volume.

The first part of Penrose's professional career may be said to have ended in 1896. The next five years were largely devoted to mining enterprises. In connection with his brother Spencer Penrose, John Brockman, and D. M. Barringer, he began to engage in projects which were to bring him great success and excellent remuneration. The first property which

he operated was the Commonwealth Mine in Southeastern Arizona, which he worked for a good many years. This mine produced about seven million dollars in six years. Penrose was the President of the Commonwealth Mining and Milling Company from 1896 to 1903. It is of interest to note that this mine was discovered along an old transcontinental trail over which wagon trains had been moving for many years though the treasures, lying almost at the surface of the earth, were not realized and discovered until Penrose and his associates took it over.

Other profitable investments during this part of Penrose's life were in iron ores in Grant County, New Mexico, eventually sold to the Colorado Fuel and Iron Company. In 1903, Penrose became interested in the development of the Utah Copper Company's property in Bingham, Utah. He was associated with D. C. Jackling, Charles MacNeill, and Spencer Penrose in this undertaking which was to develop the greatest copper mine in the United States, with a present ore capacity of about 30 thousand tons of ore per day, from prospects, which, though extensive, were hitherto considered far too lowgrade to be worked. This was undoubtedly the most successful and important of Penrose's mining adventures. Naturally much credit belongs to his associates, but there is no doubt that Penrose himself was a most important factor in the transactions and in the development of the mine. His excellent judgment and his geological knowledge led him to select enterprises which had rich future possibilities.

The time from 1901 to 1913 comprises another section of Penrose's varied life. He still took interest in his western properties and made many trips into these districts, but practically from 1901 to 1913 he spent the time in travelling far and wide. I feel sure that he planned a large work on the ore deposits of the world, and he felt that in order to present the subject adequately it was necessary for him to visit all the more important mining regions; and so we find him during these 12 or 13 years engaged in almost continuous travels. From 1901 to 1902 he visited England, Germany, Austria

Hungary, Siberia, Rumania, Norway and Sweden, Lapland, Finland, Russia, then across to Vladivostok, then to China, Japan, Philippine Islands, Malay Peninsula, and Ceylon. In 1903, he travelled to Alaska and the Aleutian Islands; in 1904, to Hawaii, Samoa, New Zealand, and Tasmania; in 1906, to South Africa; in 1907, to South America; in 1908 to the West Indies, Venezuela, and Porto Rico; in 1912, to Burma and the Rangoon country; in 1913, to Europe and to the International Geological Congress in Canada. This is truly an astonishing travel record. He visited most of the outstanding mining districts, and some of them he described in papers, mostly published in the *Journal of Geology* and in *Economic Geology*. The principal papers related to the tin deposits of Malaya, the Witwatersrand gold region, the Premier diamond mine, the gold regions of Tierra del Fuego, and the nitrate deposits of Chile. But from these thirteen years of wanderings came only ten papers, the longest containing thirty-two pages. Many of these were most excellent and attracted much attention, but nevertheless Penrose himself no doubt felt the result was incommensurate with the great effort and length of time spent. The reason for this will be further discussed in this Memorial.

From 1913 to 1923 we note few papers in his bibliography. He was increasingly occupied with other subjects, in part, no doubt financial, for by this time Penrose had accumulated a considerable fortune. He was a trustee of the University of Pennsylvania from 1911 to 1927, and very much interested in that institution. During the War he was actively connected with the National Research Council to which he gave his services until the close of the War in 1918. In 1917, he published a booklet entitled: "What a Geologist can do in War." During this period he also devoted much time to radium and uranium, and prepared a report which was published in a series known as the "Political and Commerical Control of the Mineral Resources of the World"; other reports on the same subjects were published in the Report of the Director of the New York State Museum in 1907 and as hapter X in Spurr's *Political and Commercial Geology*.

Penrose was elected a member of the American Philosophical Society in 1905, and served many years on the Publication Committee and as a councillor. He always took the deepest interest in the Society and all geological papers that were submitted were referred to him. He was President of the Society of Economic Geologists 1920 to 1921, and President of the Geological Society of America from 1929 to 1930. From 1922 to 1926 he was President of the Academy of Natural Sciences of Philadelphia, and gave a large amount of his time to this Institution. In 1927, he was appointed a member of the Board of Commissioners of Fairmont Park, in which position he was actively engaged until his death. He was also a trustee and subsequently the Vice-President of the Free Library of Philadelphia.

In 1923, he experienced a severe illness so that during the last eight years of his life he did not possess his former physical vigor. This illness no doubt more or less put a stop to his scientific activities, but, as noted above, he was engaged in numerous other enterprises and duties, which absorbed a large part of his time.

The last of his publications was read before the Geological Society of America as its retiring President, on December 29, 1930. It was entitled: "Geology as an Agent of Human Welfare." This was only six months before his death.

A list of positions and memberships held and also a list of his publications will be found at the end of this Memorial.

This history of the life of Penrose has purposely been presented in brief and condensed form. Much has been omitted. It could be expanded into a most interesting and fascinating story, and I hope that such a biography may some time be published, best perhaps by coöperation of the geologists who knew him most intimately.

My next and most attractive task is to consider Penrose as a man and as a worker.

In the first lines of this Memorial I have used the term "gentleman." Like its feminine equivalent it is a tired word, buffeted and worn by promiscuous, stupid, ridiculous usage.

And yet we are not ready to discard it. Brush away its abuses and you will recognize it as one of the noblest words in the language and there is nothing to take its place. Penrose was a gentleman; the word fits him as the glove fits the hand.

It involves a naturally good character, disposed to fairness and justice, guided in the right path by wise parents. "Ancestors" may not be needed but to many there is a strong stimulus in knowing that good and brave men have gone before you, and that it is your duty to live up to the standard which they have set. It further means self-control, strong and unyielding. It means education and manners. It means kindness and consideration towards all but particularly towards those less fortunate than you. It means at attempt to approach the highest human ideals as outlined by the masters.

Penrose was a gentleman and that is why all of his associates loved him.

I always thought that Penrose's appearance accurately reflected his character. He was tall with the build of an athlete. His features were regular, rather large with an expression of intelligence, dignity, and calm, which was rarely disturbed except when he was discussing some subject in which he was deeply interested.

It will be of interest to hear what some of his friends and associates thought of him.

Robert T. Hill [1] writes of him as follows, referring to his early work in Texas: "At intervals he would come into Austin, where he always made my house his place of recreation, and became a great social favorite with my wife and myself. In this manner we learned to appreciate and love the man and his splendid, genial disposition.

"Even to this day, when considering the conditions as they then were, I wonder how Dr. Penrose endured the brunt of field work in that environment. Only a man of his rare tact in getting along with all kinds and conditions of people, and one of his strong athletic microbe-resisting constitution, could have accomplished the task. Three other young men

[1] "Letter to J. Stanley Brown," *Bull. Geol. Soc. Am.*, **43** (1): 81–82, 1932.

drawn from Harvard at about the same time became ill or discouraged and gave up the jobs.

"Due to his good breeding and early associations, Penrose possessed the art of self-control and the ability to avoid needless discussions and arguments to a degree greater than any man I have ever met. He certainly knew how to avoid trouble in a land where nearly every man he met was ready to start an argument against the teachings of geology, on the subjects of politics or religion and on the still slumbering disagreements relative to the sides engaged in the Civil War.

"His temperament was always sunny and cheerful, and, at times, almost jovial, and he greatly enjoyed playing small and harmless jokes upon his more intimate friends.

"There had been a lapse of twenty years in our meetings when I last saw him at the annual dinner of the Society, at the Wardman Hotel Washington, December, 1930. Time, wealth, and prosperity had made but little change in the man whom I had first met as a boyish college graduate some forty-five years before. God bless his memory, for he was one of the finest of a choice few of fine men whom I have known. He had naught but kind thoughts to think and kind words to say. In him were combined all the good things that the opportunities of inheritance, education, both physical and mental, and wealth and breeding could bestow. Besides all these qualifications he was devoid of any sissylike qualities and was what we term, in the free language of our Southwest, 'a man with the bark on.'"

Dr. Whitman Cross [1] writes as follows of his associations with Penrose at Cripple Creek: "As to Penrose's personality he was a quiet, reserved type of man, not easy to get on intimate terms with, I imagine, even by those with whom he was thrown the most. But we were always interested in the same things—different phases of one job. We could begin at each meeting where we left off at the last one and soon we understood each other very well.

"I never had reason to change my early impression that

[1] Ibid., pp. 88 and 89.

Penrose was one of the simplest, most straightforward and thoroughly trustworthy men I had ever met. He was simple because his interests were always in advancing the job he had on hand. There seemed fewer side issues, less distracting pleasures, than in any other acquaintance of mine. His honesty of purpose stood out and always for something worth while. One could have confidence that he would not mislead, yet he was not inclined to tell all he knew or thought unless it was advisable. It would have been impossible to extract information he did not care to give.

"If Penrose knew how to play I never found it out. His mind seemed always on his work.

"At the close of our work at Cripple Creek, Penrose and I spent an evening together summing up our studies and estimating the future for the camp. We agreed that intelligent prospecting would develop new ore deposits in a short time, but within a limited area. I jokingly remarked that Penrose surely (and I possibly) could go out and secure abundant capital to back a thorough search for new 'bonanzas.' We might make a fortune offhand. Taking me too seriously he agreed to that but said he should, of course, not take up professional work in Cripple Creek for some years at least. It would not be fair to the Survey nor to the mine owners who had put confidence in him.

"He had many connections through which that might have been done and the Survey had not adopted, at that time, the policy of securing pledges from its employees not to engage in such practices for a term of years, but Penrose had high ideals of conduct and never violated them for personal gain, I am sure."

J. Stanley-Brown [1] writes, as follows:

"Richard Penrose possessed great capacity for making friends and as the years went by and his interests expanded, these friends grew to be a small selective army scattered over the world. It was inevitable that a man of his business astuteness should become a member of numerous business

[1] Ibid., pp. 97 and 98.

directorates and widely distributed clubs. Of the latter there were more than two score and yet he was never in the least sense a 'club man.'

"Through inheritance and training he had a complete knowledge of the pecuniary rewards to be obtained from walking wisely in the market place but the building up of his large material assets were purely a by-product of his scientific life. Geology was his outstanding love.

"It was my good fortune to know Dr. Penrose intimately during the two years preceding his death. Few persons I have met made a stronger appeal. He was free from all pettiness of life and from those habits and vices which so frequently mar social relations. He was kindly both in attitude and spirit—even gentle. There was a quietness in his demeanor and conversation that gave him the air of a silent man. His benevolences, always thoughtfully chosen, were many but not advertised. His manner was courtly and deferential. Possessing a commanding figure and charming presence, he was nevertheless modest even to the point of shyness. Life's experiences had taught him caution but when he gave his confidence it was almost with abandon. He was a born aristocrat, scientifically and personally, but without even a hint of ostentatiousness or of snobbishness. His standards in life and in science were high and unyielding—he lived his best and did his best.

"His was a buoyant nature and he enjoyed good literature, good poetry, and that type of social life where matters of real interest were reviewed and there was opportunity for outspoken free discussion.

"His manuscripts were composed with meticulous care and he welcomed any criticisms which would improve them. His esthetic sense was keen and he possessed skill in designing. It may not be known to some that he designed the medals presented by him to the two Geological Societies.

"He never married and to me seemed a very lonely man but apparently was wholly unaware of it."

There is no doubt that Dr. Penrose obtained an excellent

schooling in geology and mineralogy at Harvard. But in those days the field methods were not taught as well as they are now and like many of us Penrose had to work out some of them by himself. In some ways it is the better though more laborious proceeding. Neither were modern methods of the petrographical and mineralogical examinations of ores developed at that time. It is, therefore, in the highest degree creditable that he was able to produce, within a short time of his graduation, work like that on the phosphate deposits, the manganese deposits and the superficial oxidation of ores. Those were researches which were standards for many years and contained a great deal of new information.

His reading covered almost all of the ore deposits of the world and during his extensive travels he accumulated a vast fund of information. I know it was his intention to write a book on the ore deposits of the world. But when his travelling years were over many other things—public service and financial interest for instance—occupied so much time that he never could realize his ambition. Many interesting and valuable papers came from his years of travel but after all they were not what he had expected them to be.

I think he found that he had not devoted enough time during his earlier years to general geology and petrography. And I am sure that this failure to realize his aims proved a deep disappointment to him. A man is not necessarily to be judged by the volume of his writings. I think all mining geologists agree that Dr. Penrose was one of the most brilliant students of mineral resources of his time. During later years he took a deep interest in the American Philosophical Society; in the Geological Society of America, of which he was President in 1929–1930; also in the Society of Economic Geologists, of which he was one of the founders and its first President, 1920–1921.

A geologist is not necessarily a good engineer; but a student of applied geology—economic geology—must have this accomplishment, for his work is to locate and direct enterprises for the profitable extraction of mineral resources. And judged

by this standard Penrose was undoubtedly an engineer of high ability. His judgment evidently was sound and unerring as shown by the splendid results he obtained in mining in Arizona, New Mexico, and Utah. And it must be remembered that engineering was really only a side issue to him. Of course, he had the advantage of being able to enlist abundant financial help through his connections in Philadelphia and New York; but many men have had that, yet made a failure of mining.

When his geological work and his mining work were drawing to a close, he found himself a wealthy man; a wealth obtained legitimately, extracted from the treasures of the rocks, not acquired from others by manipulation and trickery. Any one would be justified in feeling proud of such an attainment. And now, the question would begin to take form: What to do with the money? He could not take it along; he had no immediate family. I am sure he appreciated it only as a trust, as something to be put to work for the benefit of science and posterity. His private benefactions were many, but most carefully chosen.

Knowing of his wealth many professional gold hunters, emissaries of diverse institutions, tried to turn his mind towards their own objects, but all such attempts were failures from the moment his keen intelligence divined their intentions. He would give freely, generously but only for purposes selected by himself.

I was one of those gold hunters myself. It was for a projected bibliography of economic geology, sponsored by the National Research Council. I came to Penrose, explained the matter and told him that we were all "chipping in" and said I would like to have his name on the list, for anything he would choose to give; anything would be welcome. And I was astounded, in fact quite overwhelmed by his generous response.

But as to the disposal of his wealth he took no one into his confidence, except that we all knew of his deep interest in the American Philosophical Society. And, of course, we also

knew that he would like to do something for his own beloved science and for the Geological Society of America.

Nevertheless his magnificent gifts to these two organizations, gifts unencumbered by hedges and restrictions came as a complete surprise. Penrose revealed himself in the character of the unselfish benefactor aiming only at the promotion and progress of science. He said in substance: "Here is the money; take it and use it wisely and well. There are many things I would have like to do but could not; life was too short. You try to accomplish them! Carry on!."

In crude outline I have tried to picture to you the life of one Richard Alexander Fullerton Penrose, Jr., an honorable, successful and well rounded life; successful in almost every avenue entered; a happy life I believe; but like almost every human life not exempt from pathos and disappointments. He worked for science; he died one of its benefactors.

I would like to see his tomb marked by a monument of granite on which would be deeply engraved the immortal verse beginning "Integer vitæ, scelerisque purus, ..."

WILLIAM WILLIAMS KEEN PROMOTER OF USEFUL KNOWLEDGE

WILLIAM DARRACH

(Read April 20, 1933)

OUR Society has never left its members nor the public in doubt as to its function. This is stated in its full name—The American Philosophical Society, for the Promotion of Useful Knowledge. Promotion—moving forward—upward—the word not only suggests progress—motion forward, but also to a higher plane.

Knowledge can be promoted in many ways. In the lead we find the pioneer investigators, who, by their mental processes and experiments create new knowledge, ascertain new facts, establish new principles, open up new vistas of thought and action. Then, there are those who apply these new ideas and principles to facts already known and perfect the technique of their usefulness. Knowledge is also promoted by those who having learned by themselves, or from others, teach this knowledge—the spreaders of the gospel. They teach their own confreres and their younger students and the public at large. They teach by their writings, by word of mouth, in lectures and in conversation. They also teach by their examples. But to be a pioneer, or a teacher or both, one must be ever a student. To be any of these, one must have an unappeasable hunger. One must desire to learn new truths and one must desire to help others to learn. The true teacher must do more than impart information to his listener; he must create in him that same hunger to acquire knowledge; he must stimulate him to think for himself until he too becomes a creator of new and useful knowledge. The true teacher should be to those who work with him, what water is to the desert as it flows through the irrigating ditch to transform the barren land from a gray, sterile, inactive bit of the earth's surface, to something green and alive and productive.

It is from this point of view that I ask you to consider with me one whom recent memory will call to mind as a little old man, quite frail and somewhat tottery, but still full of that marvelous optimism and cheer and human interest that lasted so vitally over a long stretch of years. William Williams Keen was a promoter of useful knowledge. He was a pioneer in his chosen fields of both anatomy and surgery. By experiment and by investigation he brought to light new facts and new principles. This new knowledge as well as that he learned from others, he applied to the art of surgery. In 1876 he heard Lister describe the principles of antiseptic surgery and became so convinced of their truth that he applied them at once at St. Mary's Hospital. He was one of the earliest American surgeons to adopt this all important advance in surgery. He continued to develop its technique until it merged into the aseptic surgery of later days.

His courageous pioneer work in the surgery of the brain was not reckless plunging into unknown territory, but was based on sound training, first as a young co-worker with Weir Mitchell, secondly as head of the old Philadelphia School of Anatomy, and thirdly when, as editor of a new edition of *Gray's Anatomy*, he had to rewrite the chapter on the brain. So, as opportunities for cerebral surgery came, they found him well prepared to undertake them wisely.

The association with Weir Mitchell was one of the most treasured incidents of his career, as he was proud to testify on many occasions. He said "his was the most stimulating mind I have ever been in contact with." In 1863, Mitchell requested Surgeon General Hammond to transfer Keen to the hospital where he and Morehouse were already installed. Years later, Mitchell told him the reason for this request was that he had already found that he could never kill him with hard work.

This tireless energy was perhaps the dominant characteristic of the man both mentally and physically. Soon after he arrived at Brown University in 1854 he realized that his school preparation had been inferior to that of many of his class-

mates. His reaction to this was redoubled effort and as a result he graduated at the head of his class. The subject of his valedictory address was "The Scholar's Sentiment of Veneration for the Past." Five years earlier, on graduating from high school, his essay was "The Prospect of Man." One may say that these topics illustrate his courage. It is worthy of note that having chosen medicine as his career he decided to spend an additional year of preparation at Brown. Thorough premedical education was rather rare in those days. His mornings were spent in chemistry and physics and the afternoons in English literature. The results of this latter effort can be seen in his clear, forceful style both in lectures and writings and in his careful work as editor.

We next find him at Jefferson and in the offices of Jacob Da Costa and John Brinton. Between the two sessions he was Assistant Surgeon in the Army and was active in the first Battle of Bull Run. After receiving his medical degree in March, 1862, he reëntered the army and served until 1864, the latter part of this period being with Weir Mitchell and Morehouse at the special nerve hospital on Christian Street. His army career was then interrupted for 53 years but in 1917 we find him a Major in the Medical Corps, serving on the Medical Council. After the Civil War there followed a period of study abroad, in Berlin with Virchow and later in Paris. In 1866 he returned to Philadelphia and began his long career of teaching and practice. He almost immediately took over the Philadelphia School of Anatomy, that extramural institution which had been founded in 1820 by Lawrance, in which Godman, Pancoast and Agnew had preceded him. In addition, he was appointed to teach surgical pathology at Jefferson. When Joseph Pancoast resigned from the Chair of Anatomy in 1873, Keen tried hard for the appointment, but without success. Defeat only spurred him to greater efforts and he became more occupied with his surgical work. In 1884, he was appointed Professor of Surgery in the Woman's Medical College, which position he held for five years. During this period he began his work in cerebral surgery and at the

First Congress of American Physicians and Surgeons in Washington in 1888 he presented three patients from whom he had removed brain tumors.

In his 53rd year, he was appointed Professor of Surgery in the Jefferson Medical College, succeeding the younger Gross. As he says "it was very late to begin a career" but for the next eighteen years he was most active as a surgeon, as a teacher and as a writer. In 1907 he resigned his professorship and retired from surgical practice, clinching the latter by eighteen months of travel abroad.

On his return home, he immediately resumed his energetic career. He had given up the scalpel but only to replace it with a pen. In 1905 he had commenced work on his System of Surgery. The last of eight volumes was brought out in 1921, each one containing about 1,000 pages. It contains articles by 138 different American and British authors. Each of these was planned and carefully edited by Keen himself, some being largely rewritten.

In 1908 he began a ten year service as President of this Society.

His interest in his Alma Mater was always active and he served as Trustee of Brown University from 1873 until his death.

Few men have championed the cause of animal experimentation more forcefully or actively than he did, beginning with a Commencement address at the Woman's Medical College in 1885, and continuing until almost the end of his days.

He was a deeply religious man and an active member and supporter of the Baptist Church.

His list of honors included many degrees and positions of distinction both at home and abroad. As he himself wrote "Both my professional and other friends have literally showered honors upon me, far more than I have ever deserved. I say this advisedly, for I think I appraise my abilities and my services far more clearly and exactly than these, my over generous friends, have done." He was particularly proud of

being elected President of the International Surgical Association in 1914. Because of the war, the next meeting was not held until 1920. At the age of 83 he not only went to Paris to preside but spent a good deal of the preceding months in studying French so that he might better use the language of the hosts of the Society.

His complete bibliography fills many pages of titles of books and papers on anatomy, surgery—both civil and military, and on immortality. Through these writings he was most active and efficient as a spreader of the gospel. During his long period as a teacher, he was himself what he called Mitchell, a "yeasty man." He fermented others. Even after his retirement, he continued to impart information and to stimulate others to think. He was a brilliant conversationalist and a most active correspondent. I know of one dean of a medical school in another city who looked forward to the monthly letter from Spruce Street. Each one meant not only an answer but a definite chore to be done, but one always worth doing. It was hard to resist that glowing enthusiasm, that young point of view, that eager optimism, that catholic, broad outlook. Nor could one easily fail to be infected by those merry twinkling eyes and the ready laugh.

He was a clean man who hated vulgarity. He was a loyal man, loyal to the ideals of his profession, loyal to his friends. He was always interested in young men, stimulating them, ready to listen to their theories, believing in them. His triumphant, firm belief in immortality was an outstanding quality.

Few men have been members of this Society for 48 years and fewer, yet have as consistently carried out its function of promoting useful knowledge. For more than ninety years he was a grand, young man!

PREHISTORIC RESEARCH IN THE NEAR EAST

GEORGE GRANT MACCURDY

(Read April 21, 1933)

THE story of prehistory is beginning to take shape. The Old World is the ample stage on which the first acts of the human drama took place. In the past we prehistorians have given most of our attention to the wings of the stage rather than the center. The Near East, which is the center of the stage, is now receiving the consideration which its strategic position would seem to justify. Under its surface there may lie hidden some of the most important keys to a cultural kinship which bound the three continents together in prehistoric times. In this brief survey I shall confine myself to the prehistoric; for the Near East may yet prove to be a center of diffusion as dominant prehistorically as we know it to have been protohistorically and historically.

Ever since the American School of Prehistoric Research began its work (in 1921), I have had in mind that it should help to explore this region, where it seemed certain from previous finds that much remained to be done in the domain of prehistory proper. This determination received an added impetus from Turville-Petre's discovery in 1925 of the so-called Galilee skull (Neandertal) in the cave of Zuttiyeh near Tabga. The following year Mrs. MacCurdy and I visited Palestine and Syria to attend the International Congress of Archæology and especially to do some reconnaissance work.

During the spring of 1928 Miss Dorothy A. E. Garrod began the excavation of the cave of Shukba for the British School of Archæology in Jerusalem, assisted by two students trained in our American School of Prehistoric Research. Shukba is in Judea some 27 km. northwest of Jerusalem. The cave, which was discovered in 1924 by Père Alexis Mallon, opens on the Wady en-Natuf at 322 m. above sea level. Here

Miss Garrod uncovered a sequence of cultures beginning at the top with a deposit containing relics dating from modern times to the early Bronze Age. Below this was a rich layer of Mesolithic Age with quantities of microlithic flints and skeletons of a dolichocephalic race. This small long-headed race, Sir Arthur Keith describes as early Mediterranean. The bottom level contained an Upper Mousterian industry closely resembling that found with the Galilee skull in Mugharet ez-Zuttiyeh, and differing from the Mousterian of Europe in its more delicate technique and in a greater variety of forms, some of them foreshadowing the upper Paleolithic. At the base of this level, a large Neandertal molar and a portion of a skull, including the glenoid fossa, were found.

In October 1928 our School made an expedition into Iraq jointly with the British Sladen Fund, Miss Garrod being in charge. The region explored was the district known as Sulaimani. The city of Sulaimani lies some 265 km. northeast of Baghdad. Many Paleolithic caves and rock shelters were located. The cave at Zarzi was completely excavated and the Dark Cave (Ashkot-i-Tarik) at Hazar Merd was partially excavated. Zarzi was rich in remains of the Upper Paleolithic (Aurignacian). Hazar Merd yielded remains from three horizons: Mousterian, Aurignacian, and Neolithic. This is the first work ever to have been done in the Paleolithic caves of Sulaimani.

Our attention was next turned to the region of Mount Carmel, Palestine. In 1928 quarrying operations near Athlit brought to light two interesting prehistoric objects: the head of an animal carved on bone and a shoulder blade with a circular perforation. These were brought to the attention of Miss Garrod by the Department of Antiquities and the British School of Archæology in Jerusalem; she in turn notified our School. In view of the emergency, it was thought best to postpone further work in Iraq and at Shukba. Through Miss Garrod our School and the British School therefore arranged for a series of joint expeditions to follow up the accidental discovery reported from Athlit. There have since followed

four spring campaigns and one autumn campaign. A sixth campaign is now (1933) in progress.

The group of caves is in the Wady al-Mughara; three of these have been productive, yielding an enormous quantity of material, much of which is of the utmost importance to prehistory. The three caves are: Mugharet el-Wad (Cave of the Valley), Mugharet es-Sukhūl (Cave of the Kids), and Mugharet et-Tabun (Cave of the Oven). The caves are situated some 19 km. south of Haifa (Fig. 1). The Cave of the Valley

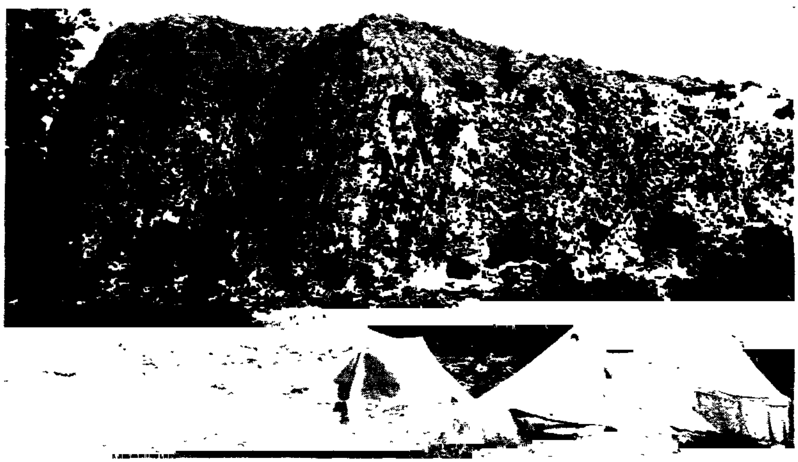


FIG. 1. Face of the escarpment in which the three caves: Mugharet el-Wad (near the center), M. es-Sukhūl (at the left) and M. et-Tabun (just off the picture at the right) are located.

occupies a central position; the Cave of the Kids is a short distance up the valley, and the Cave of the Oven, down the valley but at a slightly higher level in the escarpment. In addition we have begun the excavation of Mugharet el-Kebara at the colony of Zichron Jacob, 16 km. south of the Wady-Mughara group of caves. Kebara has already yielded some remarkable Natufian bone carvings and bids fair to reveal a culture sequence second only to Mugharet el-Wad.

Mugharet el-Wad.—During the seasons of 1929 and 1930, excavations were practically confined to this the largest cave of the Wady-Mughara group. It has disclosed the most com-

plete prehistoric sequence thus far known in Palestine, the layers from above downward being as follows:

A. In the Cave

8. Recent, including Byzantine, Arab, Roman, and Hellenic
7. Bronze Age
6. Mesolithic
5. Upper Paleolithic with Capsian affinities
4. Middle Aurignacian
3. Lower Middle Aurignacian
2. Layer of Erosion with mixture of Aurignacian and Mousterian
1. Mousterian

B. On the Terrace

8. Recent
7. Bronze Age
6. Mesolithic (two levels).

The artifacts are of flint, chert, bone and horn. In layer 1 there is a preponderance of Levallois flakes. Triangular flakes are more abundant than scrapers. The industry resembles that from Shukba and Mugharet ez-Zuttiyeh. Layer 2 must have been formed by water action during a period of intense rainfall, when preëxisting Upper Paleolithic and Mousterian layers were destroyed by erosion. Waterworn flints from the same layer in Shukba were reported by Miss Garrod. A similar phenomenon was discovered by Peyrony at the classic station of Le Moustier (Dordogne), except that at Le Moustier the layer of waterworn flints is the fourth in a series of five Mousterian horizons counting from the bottom upwards.

In layer 3 the industry consists of rather massive steep scrapers, rostrate scrapers, spiky flint points like those from Krems (Austria) and Font-Yves (France), bone points made from the metacarpals of the gazelle, etc. In the Middle Aurignacian (layer 4) rostrate scrapers and beaked gravers are characteristic. The Capsian (layer 5) contains large flint

knives, Châtelperron type, identical with those found in the Lower and Middle Capsian of northern Africa. Steep scrapers and rough gravers are abundant.

The Mesolithic (layer 6) differs completely from any of the preceding culture levels. The flint artifacts range from fair-sized blades to true microliths. Chert was employed in the manufacture of rough massive picks. Microlithic flint crescents were found by thousands. Other tools include micro-gravers, *dos rabattu* blades and sickle blades with edges highly polished by use. Among bone objects are points, pins, small harpoons with barbs on one side only and sickle blade hafts

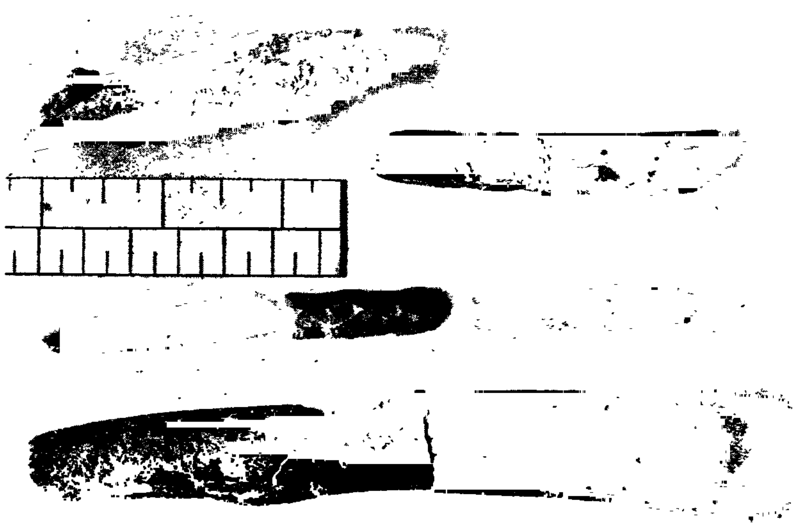


FIG. 2. Sickle-blade hafts, from layer 6. Mugharet el-Wad. Natufian (Mesolithic) Epoch.

with deep longitudinal grooves (Fig. 2). The sickle blades, limestone mortars and pestles of basalt presuppose agriculture, which seems to have antedated pottery making.

Skin rubbers were made from the antlers of *Dama mesopotamica.* A majority of the pendants and beads of bone are pearshaped, probably copied from the canine teeth of the deer. Objects of art include the head of a young deer carved on the

proximal end of a bone sickle-blade hafting and a small human head carved from a piece of banded calcite. In this connection it should be mentioned that René Neuville has just found in the Cave of Oumm-Zoueitina, south of Jerusalem, a Natufian figure of a ruminant carved in stone.

On the terrace the Mesolithic was divisible into two levels. (Fig. 3). In both the lunate microlith was most typical and

FIG. 3. Rock-cut basins and pavement on the terrace at M. el-Wad, as seen from the mouth of the cave. Natufian Epoch.

most abundant. In the upper level these were small with back trimmed vertically (*dos rabattu*), in the lower level they were larger. Micrograyers were abundant and sickle blades rare in the upper level, while the reverse was true of the lower level. Rare in the upper level, bone implements were plentiful in the lower level, including pendants, harpoons and sickle-blade hafts. Inside the cave only the lower level was represented. The Mesolithic at Shukba, valley of the Natuf, corresponds to the upper level at Mugharet el-Wad. It was christened *Natufian* by Miss Garrod. We have therefore at Mugharet el-Wad both Lower and Upper Natufian. The

Lower Natufian rests directly on the rock-cut platform and basins of the Mugharet el-Wad terrace.

At Mugharet el-Wad human skeletal remains have been found in the Upper Paleolithic as well as the Natufian. Two lower jaws, a piece of the frontal, an astragalus and fragments

FIG. 4. Skeleton with circlet of shells, from layer 6. M. el-Wad. Natufian Epoch.

of a child's skull were found in the Lower Middle Aurignacian (layer 3). Both Upper and Lower Natufian levels have yielded numerous skeletons as well as a large quantity of scattered bones. In 1930 eleven skeletons (four adults and seven children) were found in Chamber I of the Cave. For the most part the skeletons were lying on the side (right or left) with legs flexed. In several cases the body must have been bound before *rigor mortis* set in. Seventeen skeletons and many scattered bones were found in 1931 and at least six in 1932. A group of three skeletons were arranged in a circle, head to feet, with a broken limestone mortar in their midst.

The Natufians were fond of ornament. They made special use of dentalia shells, perforated teeth and bone pendants, many of the latter roughly resembling in shape canine teeth of the deer (Figs. 4 and 5).

FIG. 5. Skull of the skeleton in Fig. 4.

Mugharet es-Sukhūl (Cave of the Kids).—This cave was occupied only during Mousterian times (Fig. 6). The deposit half filling the cave and covering the terrace in front to a depth of from 2 to nearly 3 m., consists largely of brown to black breccia, from which over 8,000 implements of Mousterian workmanship were recovered in 1931 and 1932. It was here that McCown found nine human skeletons, one in the spring of 1931 and eight in the spring of 1932. All belong to a race closely akin to Neandertal man of western Europe. The skeleton found in 1931 was that of a child not over three years old. It was buried toward the center of the terrace in a tightly flexed position, facing south and into the cave. Number II is an adult and represents a disturbed bur-

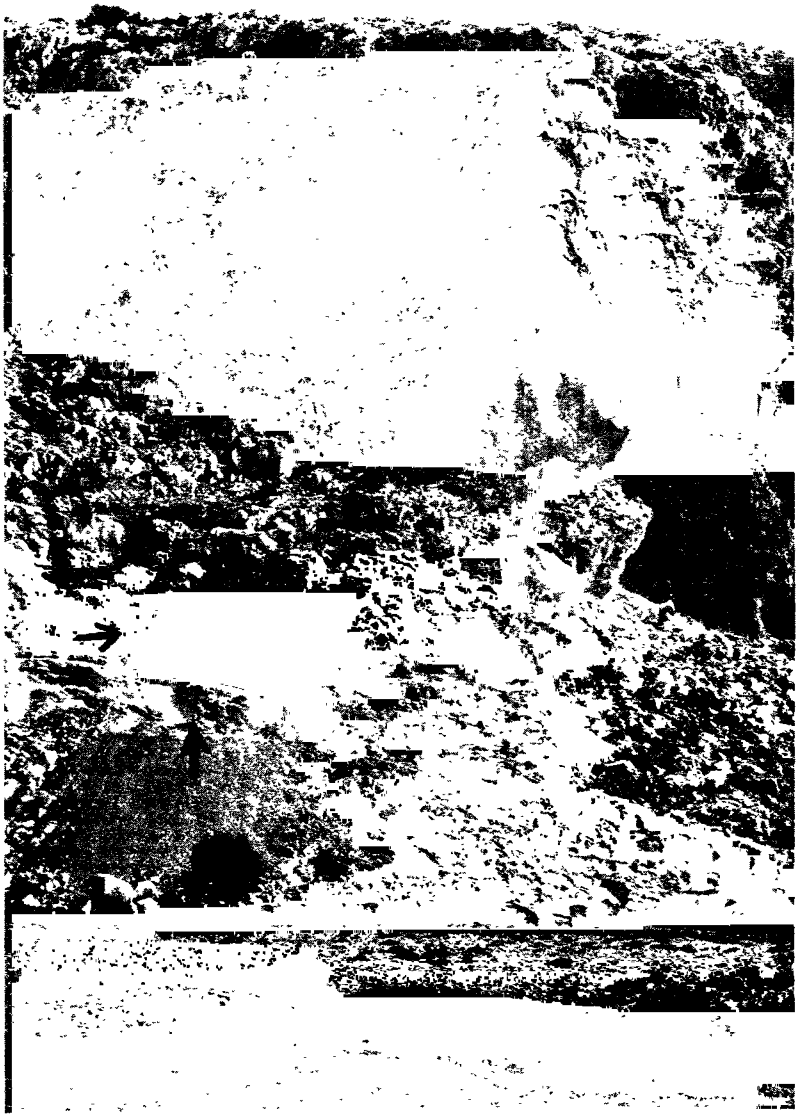


FIG. 6. Mugharet es-Sukhūl, as seen from across the Wady al-Mughara.

FIG. 7. Skeleton No. IV, from the terrace in front of M. es-Sukhūl. Mousterian Epoch.

FIG. 8. Skeleton No. V, from the terrace in front of M. es-Sukhūl. In the angle formed by the arm bones is the lower jaw of a wild boar. Mousterian Epoch.

ial; arms, brain case, lower jaw and eight teeth were the only parts recovered. It is the only individual not imbedded in the breccia matrix. Number III is an adult; the flexed leg bones were the only parts found. Number IV is an adult

FIG. 9. Skull of skeleton No. V.

approximately complete: cranium, lower jaw, long bones, pelvis, hands and feet. The legs were flexed (Fig. 7). Number V is an adult nearly complete with excellently preserved cranium and lower jaw (Figs. 8 and 9). The legs are flexed. The left arm lies across the body while the right arm is flexed. In the angle formed by the lower left arm and the right humerus lay the mandible of a large wild boar. The left ulna and radius lay across this mandible, so that the presence of the latter can hardly be fortuitous. The right tusk and both rami of the mandible had been broken away. Numbers VI, VII (young adult) and VIII (child) are fragmentary. Number IX is an adult, fairly complete, with a tremendously thick skull.

That these were all burials there can be little question. Contraction of the limbs is a feature common to all. The limb bones are long and massive indicating heavy musculature and stature above the average. The curvature of the femur and retroversion of the tibial head suggest a stooping posture.

FIG. 10. Entrance to Mugharet et-Tabun.

Mugharet et-Tabun (Cave of the Oven).—This cave consists of an inner and an outer chamber, the inner chamber being a well (or chimney), which runs up to the top of the cliff and has an opening 4.5 m. in diameter. The outer chamber opens on a terrace covered by relic-bearing deposits (Figs. 10 and 11). The work of the autumn season (1932) was confined largely to this cave, which has proved to be much deeper and more expansive than was anticipated. It is planned to complete the excavation during the spring season of 1933 now in progress. Miss Garrod is in charge. A section 5.25 m. thick has been exposed on the terrace with a sequence of levels as follows:

Fig. 11. M. et-Tabun. Section of the deposits showing all but the topmost layer (*A*). A human skeleton with chinless lower jaw and a lower jaw of different (Sukhūl) type were found in layer *C* (layer 4 of the text). The measuring rod is 2 m. in length.

6. Mixture of Mousterian and Recent
5. Mousterian
4. Mousterian. Dark hearth with flint implements; Levallois flakes resembling in size those from Baker's Hole (Northfleet). Human skeletal remains, rhinoceros, hippopotamus
3. Mousterian, a few hand axes. Large ox, *Hemionus*, hyena
2. Mousterian with Levallois affinities. Points of the Still Bay type (South Africa)
1. Early Mousterian, or perhaps Acheulian, many superb hand axes

Level 1 has yielded an abundance of flint implements totally different from any thing in the levels above. They resemble the very old Mousterian of High Lodge (Suffolk) and include many superb hand axes and great scrapers. The tooth of an elephant was found in this level, which is probably contemporary with the interglacial horizon at Ehringsdorf-Taubach. It may be that we have here a level of approximately the same age as that reported recently from the Cave of Oumm Qatafa, south of Jerusalem, by René Neuville and classed by him as Upper Acheulian.

The human skeletal remains found in the Mugharet et-Tabun prior to April, 1933, include the following from the terrace: a femur, a massive lower jaw and a practically complete skeleton, all in layer 4, and a femur in layer 1 at a depth of 5.60 m. from the surface. The teeth of a child were found in the chimney at a depth of 7.10 m. from the top of the escarpment. The massive lower jaw resembles those found by McCown in the Mugharet es-Sukhūl. The skeleton is small but fully adult and may therefore be that of a female. The bone of the skull is relatively thin. The development of the frontal torus is in marked contrast with the comparative delicacy of the rest of the skeleton. The legs were flexed. The skeleton came from a very dark hearth and the bones of the feet are blackened by fire. Flint flakes were abundant in the same matrix; the remains of a huge turtle and of a rhinoceros were found near the skeleton. The most remarkable single

feature is the chinless lower jaw, while the lower jaw found 90 c. deeper in the same layer 4 has a fairly well developed chin (Fig. 12). The finding of these two lower jaws, in fairly

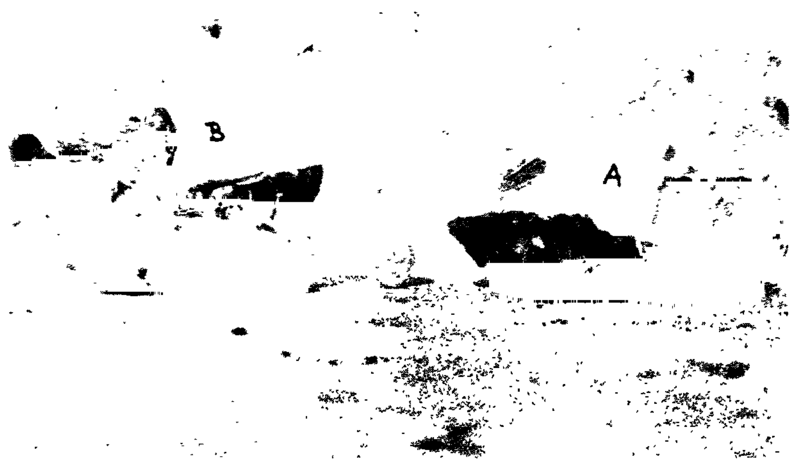


FIG. 12. Human lower jaws of widely different types, both from the same layer (*C*) in M. et-Tabun. Lower jaw No. *A* belongs with the skeleton. Mousterian Epoch.

close proximity and differing so widely in form, brings to the fore an interesting problem. Is the difference racial, or is it individual bordering on abnormality? The latter would seem to be the logical explanation.

JIVARO SHAMANISM

MATTHEW W. STIRLING

(*Read by title, April 21, 1933*)

The Jivaro or Shuara Indians live in small household groups located principally upon the headwaters of affluent streams of the upper Maranon, Santiago, Pastaza and Morona rivers in eastern Ecuador and Peru. Their tribal groupings are of an evanescent nature, and are marked by an almost complete absence of any political organization other than temporary alliances to assist in the conduct of war. The Jivaros are best known perhaps for their elaborate system of blood revenge with its attendant ceremony of shrinking human heads. Lacking political units, they also lack political offices. Because of this fact the shaman, or wishinu, takes rank as the most important and influential individual of his group.

The practice of shamanism among the Jivaro Indians is, of course, basically conditioned by their religious beliefs and conceptions of life and nature. The impersonal magical force which gives supernatural properties to certain classes of animals, plants or natural phenomena is called by the Jivaros *tsarutama*, more or less the equivalent of the Iroquois *orenda*, the Siouan *wakanda*, or the Polynesian *mana*. Possessing this force or quality are a large group of spirits, usually of an animistic nature, as well as all of the animals and plants which are mentioned in the sacred origin myth. Certain birds, fish, insects, reptiles and plants contain *tsarutama*, each of which is responsible for producing certain important effects upon the welfare of man.

In times of war an attacking party always attempts to kill the wishinu of their enemies as early in the fight as possible so as to free themselves from possible injury by the spirits which he controls. When a wishinu is killed, his enemies never shrink his head because of their fear of the spirits contained

therein. The head of an ordinary victim in war is shrunken in order that the spirit will be bottled up and thus rendered harmless.

Not only is the Wishinu respected for the power which he wields, but he is likely also to be the wealthiest man of his group because of the high prices which he charges for his services in curing. He may also draw pay for sending sickness for someone who desires revenge upon another person. There can be no doubt that the wishinu believes fully in his powers. He is thoroughly conscientious as a practitioner and spends many long sleepless nights working with his patients. He is regulated by a code of ethics whereby he will respond to a call however inconvenient it may be for him to do so. This conscientiousness may be partly regulated by the fact that the wishinu is held personally responsible in the event his patient dies and, being so responsible, is liable to compensation or blood revenge. As a curing doctor, it is the task of the wishinu to identify the particular spirit which has invaded his patient and then, through his knowledge of the method of controlling this spirit, to call it forth.

All of the principal nature gods or culture heroes contain powerful *tsarutama.* These, as a rule, are personified and are assigned particular dwelling places. Thus, for example, Piribri, the Rain God, lives in the solitudes of the cloud-wrapped mountain Cuticu. Therefore, the mountain itself is charged with his *tsarutama.* The trail from Mendez to Yaupe crosses Cuticu, and no Jivaro will speak while crossing the summit of the mountain because Piribri likes solitude and silence. If offended by disrespectful invasion of his dwelling place, he causes heavy rains to fall upon the traveler, produces floods in the streams and makes the way difficult and dangerous. Likewise, Pangi, the great anaconda River God, dwells a captive in the Pongo Manseriche, the great cataract of the Maranon, and the same taboo of silence is observed by the Jivaros in passing through this gorge. Etsa, the sun, and Nantu, the moon, contain powerful *tsarutama* which influence all that occurs on earth. The chonta palm, one of the plants

mentioned in the sacred origin myth and much used by the Jivaros in making weapons, utensils and even their houses, also contains *tsarutama*. The Indians believe that a lance made entirely of chonta wood is more effective in warfare than one which is tipped with iron.

Fire is supposed to possess within it two influences, one destructive in nature and the other beneficial. The Jivaros consider fire to be a female spirit and consider this conduct typical of the sex. A sure way to cause offense to a Jivaro is to throw a piece of paper in the fire while in his house. The destructive and the beneficial forces within the fire ordinarily neutralize one another. Paper with writing on it, however, the Jivaros know carries white man's messages, and they believe that it might carry information which would give the destructive element in the fire the upper hand and thus bring about harm to themselves.

In accordance with the animistic ideas of the Jivaros, all plants and artifacts possess male or female souls, a fact which must be taken into consideration at all times. Thus, since most domestic plants, such as manioc, are female, it is only the women who may cultivate them and prepare certain sorts of food from them. In the same manner, pottery is female and must be made and cared for by the women. A man's weapons, or in fact any object manufactured by a man, has a male soul. It would be unthinkable to a Jivaro that a man's shield should be made by his wife or that a man should make an earthenware vessel.

To illustrate the manner by which a man becomes a shaman and how he performs his many duties, I present the experiences of Tendetsa, a prominent wishinu of the Yaupe river. Tendetsa first determined to become a wishinu through his interest in watching other wishinus operate in curing the sick. It so happened that among his relatives there was no wishinu to look after those who became ill and he felt a desire to perform this service.

After making up his mind that he would become a wishinu, if possible, he went to consult Usatcho, an old wishinu of the

Yaupe tribe, who is now dead. A bargain was reached whereby Usatcho agreed to train Tendetsa. It was necessary for Tendetsa to pay a high price for this course of training. He gave Usatcho many things, including gifts of food, ornaments, clothing, and other articles of considerable value. The period of training lasted for one month, beginning and ending with the full moon.

The principal function of a wishinu is that of a curing doctor. In order to be able to cure sicknesses, he must learn how to gain control of the various spirits which cause different classes of illness. Once in control of these spirits, he likewise has the power to send sickness into people as well as the power of calling it forth, a fact which makes the wishinu the most feared and the most respected member of his tribe.

Sickness is carried on an allegorical blow-pipe dart called *dsensac*. One of these darts exists for each class of illness. During the process of becoming a wishinu it was necessary that Usatcho give Tendetsa control of each *dsensac*. The course of instructions took place in the house of Tendetsa. Before beginning his instructions, in order to determine his eligibility, he was sent out by Usatcho at night to catch a fish called chumagaie. He was given bait which Usatcho previously rubbed under his armpit and was instructed to throw in the hook with closed eyes, not looking until the fish was caught. He obeyed these instructions and succeeded in catching the fish which Usatcho then told him to eat. Then Usatcho went into the forest and collected a bunch of leaves called *sasangu*. These, when waved in the air, make a swishing sound and are used for the purpose of calling the spirit desired.

The first day of his initiation, Tendetsa fasted, but, with Usatcho, took quantities of *piribri* (an herb which is chewed and mixed with water, in which form it is taken as a drink which has a narcotic effect). The two men sat facing each other during the entire time. On the second day, the same routine was followed excepting that the narcotic *mycot* was taken instead of *piribri*. On the third day, the drug was changed to *ahinhibri*. On the fourth day, *sango* (tobacco) is

made into a strong liquid infusion which is snuffed up the nose, each blowing the liquid up the nose of the other in large quantities. On the fifth day, *natima* is taken. During the next five days this cycle is repeated, beginning with *piribri* on the sixth day and ending with *natima* on the tenth day. During all of this ten day period, no food whatever is taken. On the close of the tenth day, the initiate ate two ripe plantains, mashed and mixed with water, and later he ate two green plantains roasted or boiled.

At the close of the tenth day before taking the food, they blew into the air calling to Pasuca, the spirit of the blow-gun dart. After ten days of taking quantities of drugs without food, they were very light headed, especially the initiate. They sat waving the sasangu leaves and blowing, repeating songs to Pasuca until he appeared finally to them in the form of a bold warrior. When Tendetsa saw him, he called out to Usatcho, who began to massage his body rigorously. During this operation he became unconscious. When he recovered, his body was sore from head to foot and he knew then that the spirit of Pasuca had taken possession of him.

During the next twenty days they ate only a few boiled green plantains each day and drank a little *nijimanche*, a liquid decoction of manioc, which was very carefully strained. During this period they also ate cameron, a small reddish fish. For another month this diet program of the last twenty days was followed, excepting that they ate only snails in place of cameron. The green plantains and the mesato were taken as before. During the last twenty days of the first month, Tendetsa was instructed in the method of controlling the various spirits of disease which are borne by Pasuca.

The first of these spirits is Minura, the spirit of the cashpa, or ray fish. This is the strongest of all of the disease spirits and consequently the most difficult for the wishinu to remove. In order to call Minura, the sasango leaves are waved persistently after the wishinu has taken *natima*, during which time he calls upon the spirit by name, asking him to come forth. He sings songs addressed to the spirit, meanwhile

playing upon the small shaman's drum. When treating a patient, the wishinu at intervals sucks the afflicted part of the patient and if successful in his efforts, which may last for many hours or even days, the spirit will enter the mouth of the wishinu, who then rushes out of the house, gagging and retching while he spits or vomits the spirit out of his own body. After this has been done, with many gesticulations he orders the spirit to leave and not to enter the house again. He makes a complete circuit of the house, pausing at intervals to repeat the performance. As he does this, he is helped out by the people within the house, all of whom are shouting for the spirit to go away. The treatment is always carried on at night and in the darkness, no lights being permitted in the house while the wishinu is operating. The spirit Minura is described as looking like a bearded warrior. Because of the difficulty of calling this spirit, it is necessary for the wishinu to take *natima* three or four times in order to give him extra power for the purpose. When the wishinu desires to send Minura into some person in order to give him the sickness, he goes alone to the river where the cashpa lives. The spirit is called out by blowing tobacco smoke towards the river and when Minura appears to the wishinu he sends him by means of the blow-gun dart Pasuca into the body of his intended victim. The same songs are sung as are used in calling him out from the body of a patient. Because of the difficulty before mentioned of calling out this powerful spirit, the wishinu charges exceptionally high rates for his treatment, sometimes as much as a gun. If the neophyte shaman does not succeed in producing Minura's appearance during his training, he will be unable to do so as a practitioner. The same holds true of all the other spirits.

The second of the disease spirits is called Amaron. This is the spirit controlled by *napi*, the snake. He is called out in cases of snake bite or other poisonous bites of similar nature. The method of treatment is exactly the same as in the case of Minura, excepting that this spirit responds more easily and the wishinu does not have to work as hard nor as long. The

songs which are used in calling are, of course, special songs to Amaron. In addition to the magical treatment, the patient who has been made sick by Amaron is also given an enema of crushed red pepper. The wishinu fills his mouth with the fiery liquid and, by means of a bamboo tube, blows it forcibly into the rectum of the patient. In order to send Amaron into the body of anyone he desires, the wishinu goes into the forest and calls the spirit in the same manner as described for Minura, using, of course, the appropriate songs.

The third disease spirit is Yabi. This spirit is described as seldom appearing. It is said to have no face and is "like a door." The wishinu in calling it addressed it as a door, calling upon it to open. Yabi causes barrenness in women. The method of procedure in controlling this spirit is the same in general as the others.

A fourth spirit is Chingi. This spirit is controlled by the toucan (Tsucanga) and by the woodpecker (Tatash). All stomach troubles are caused by Chingi. The beak of the bird pecks at the entrails, thus producing the illness.

All localized aches and pains in various parts of the body other than in the stomach are caused by a fifth disease spirit known as Morovi. This spirit is possessed by the bird which the Jivaros call by the same name. The treatment of these sicknesses is as before described. When the wishinu wishes to send the spirits of Chingi or Morovi to someone else, he goes into the forest and calls them by blowing tobacco. Such parts of the forest are selected as are known to be occupied by the birds which represent the spirit.

The sixth disease spirit is Tunchi, the spirit of the biting insects, such as ants. This spirit produces all rashes, itches and skin eruptions. Tunchi is controlled by the wishinu in a similar manner to the other spirits.

It is interesting to note that when a wishinu has sent a disease spirit into a man he does not have the power to cure this individual, although a cure might be effected by another wishinu. The reason for this is because the spirit would be annoyed at being called upon to undo something that he had been directed to do.

After the first month of training, during which the new wishinu has learned control of the spirits, he undergoes a strict diet for another month and thereafter there are a number of foods which are taboo to him. He cannot eat deer, armadillo, peccary, wild pigs, tapir, cholo monkey, manatee, peanuts, chonta fruit and many other animals, birds, fish and vegetables. The reason for this taboo is that all of these possess *tsarutama*. Should he eat any of these foods, their *tsarutama* would enter him and neutralize or confuse the particular class of *tsarutama* that he might be attempting to isolate for his particular purpose.

Not all diseases are caused by spiritual invasion. Colds, fever, dysentery and others are regarded as natural sicknesses in which no spirit is involved. The Jivaros are very much afraid of contagious diseases. Whenever a man develops a cough or symptoms of some contagion, the other Indians abandon the house and disappear into the bush where they will have no contact with him. In the same way, they will avoid all persons who have been in contact with the sick person after he contracted his illness.

It is also the duty of the wishinu to treat natural diseases. The remedies used are generally herbs or extracts taken internally or applied externally according to the nature of the trouble. In the case of broken limbs, chicle is put around the injured member as a cast after first setting the bone. Leaves are wrapped around this and wooden splints placed over the leaves and fastened by means of vine wrappings.

The wishinu has many duties apart from his function as curing doctor. In fact, while this may be considered the most important of his occupations, it comprises considerably less than half of his duties. When a young man wishes a particular woman to become enamored of him, he calls upon the wishinu to prepare a love potion, which requires the mixture of several articles containing the requisite *tsarutama* and which can be prepared only by the wishinu. He also has control over the great body of nature spirits. When necessary, he is called upon to contact Piribri, the Rain God, in

order to produce storms and floods or to stop them as the case might be. In order to call Piribri, he blows smoke in the direction of his dwelling place, using the proper songs, much in the same fashion as he calls upon the disease spirits. Likewise, if he wishes to call on Pangi in order to overturn the canoe of some enemy or to control the river in any way, he can do so. All unexplained sudden storms or floods are attributed to the activity of some enemy wishinu. The wishinu is also called upon to determine action in many tribal matters; for example, when a chief dies leaving no son the wishinu is called upon to take *natima* in order that it will be revealed to him who the successor of the chief should be. The wishinu also plays an important indirect function in the conduct of warfare. If a man dies in his tribe, he takes *natima* and by this means determines which wishinu of some other tribe sent the fatal illness. This, of course, applies only to death brought about by the disease spirits and not to deaths from natural causes. Frequently a Jivaro desires to join some tribal unit other than his own. In this case, his eligibility is determined by the wishinu.

ARCHEOLOGICAL DISCOVERIES IN THE MAYA AREA

CYRUS LONGWORTH LUNDELL

(*Read by title, February 3, 1933*)

IN THE fall of 1931 I made an expedition to the scientifically unknown southern portion of the Yucatan Peninsula, primarily for the purpose of studying the flora, especially in its ethnobotanical and economic aspects, but also in the hope of locating any Maya ruins that might be buried in the jungle.[1] From Champoton, on the coast, I went up the Champoton River to the village of Kanasayab, the terminus of the tramway line which runs into the interior. The tramway was originally built to haul out logwood, the source of hæmatoxylon dyes, but now it is used almost entirely to carry in merchandise and bring out chicle gum, for dyewood has been of little value since the development of synthetic substitutes.

The jungle of southern Campeche begins at the coast and stretches, an unbroken forest, across the Yucatan Peninsula from the Gulf of Mexico to the Caribbean Sea. The tramcar on which we rode on top of the cargo passed through a low narrow tunnel in the dense and ever encroaching vegetation.

At the end of the first day, after passing through the villages of San Dimas and Yacasay, we arrived at the uninteresting village of Yohaltun. At the village of Pustunich, not far away from Yohaltun, there are three large Maya sculptured "idols" that have possibly been standing for a thousand years. The Indians have built a thatched shed over two of the carved stelæ, which are called the "gods of Pustunich." They are much revered by the Indians. These stelæ are important archeologically, and a study of them may reveal some of the history of Chakanputun, the name by which the ancient Maya designated this north-

[1] This paper deals only with the archeological explorations. Accounts of the flora and of chicle production are to be published elsewhere.

western part of Campeche. Pustunich is a new Maya site of unusual possibilities, hitherto unknown to archeology.

The next morning we continued on the flatcar and arrived in Juarez (La Gloria) late in the evening. From Juarez the roads lead south and west into the virgin "bush," where chicle, the basis of chewing gum, is exploited. (Either secondary or virgin forest is called "monte" by Spanish-speaking and "bush" by English-speaking residents of the Yucatan area.) From Juarez we reached Tuxpeña by two days of hard riding. The trail was almost impassible and many times the mules wallowed belly-deep, and constantly lurched against the tree trunks in their efforts to find firmer footing. September and October are the wettest months of the wet season, which lasts from June to February.

Tuxpeña is in the center of southern Campeche (Fig. 1), about seventy miles north of the Guatemalan border. It is the chicle receiving station of the area, and here I made my headquarters from the fourth of October to the end of February.[1]

The exploitation of the sapodilla forest for chicle has made the remote interior accessible. Roads and trails have been opened to bring out chicle by trucks and mule-trains, and as the demand for gum has increased, it has been necessary for the chicleros (gum gatherers) and the contractors for whom they work to penetrate deeper and deeper into the great forest covering the southern half of the Yucatan Peninsula. These chicleros, many of whom are Maya Indians, have opened the way for the scientific explorers who have long delayed entering these regions which appear formidable, yet in reality are not too difficult to traverse. For almost three decades, since the beginning of chicle exploitation in that region, there have been trails and roads penetrating every section of southern Campeche.

Before the chicleros invaded Campeche, there were isolated villages of bush Maya scattered throughout, and they still

[1] The Mexican Exploitation Company of Campeche maintains Tuxpeña as a branch office. The writer wishes to express his thanks for the cooperation received from this company during the five months spent in southern Campeche.

remain in spite of the struggle that has been waged against them by gum exploiters. From their agricultural clearings (milpas), and the bush with its abundance of wild game, fruits, and useful plants, they obtain all the necessities of life. These Indians have a marvelous knowledge of the flora and

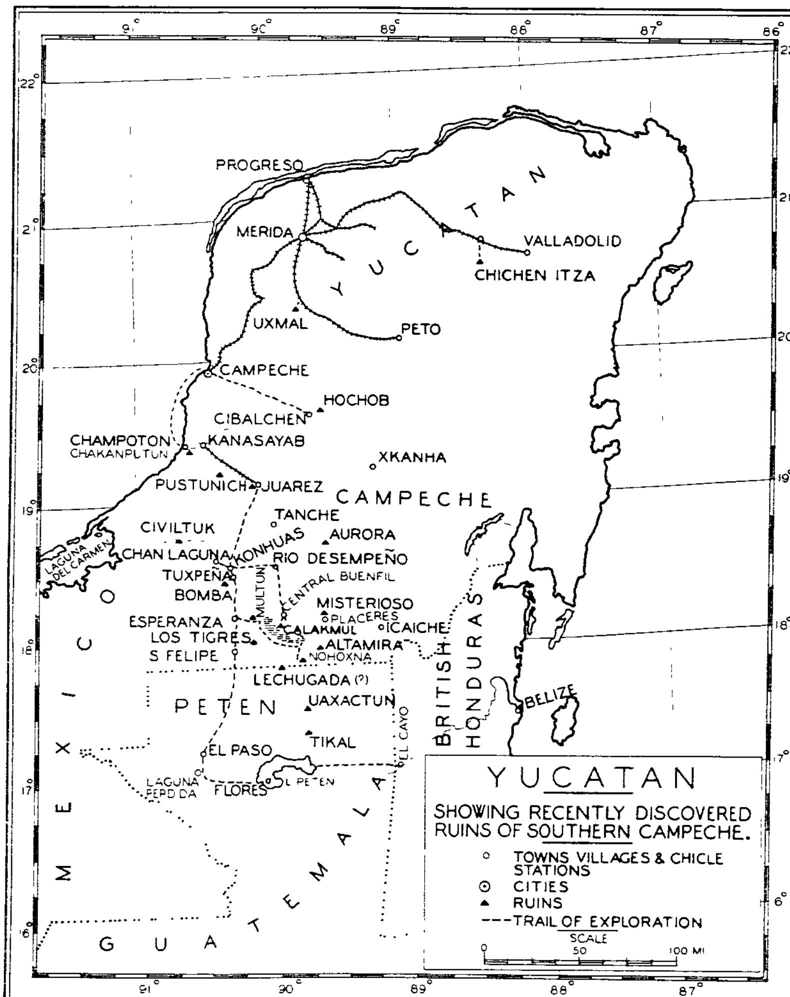


FIG. I.—MAP OF YUCATAN. Showing Recently Discovered Ruins of Southern Campeche.

fauna. They have undoubtedly lived in the interior forests continuously for ages, possibly since the time of the early Maya culture of the south.

I venture to say that these bush Indians have visited the stone ceremonial centers of their ancestors through the centuries. Some of them probably remained in the old cities long after their abandonment as cultural centers. It may be that until within the last hundred years they cleared away the jungle growth from at least some of the old temples and made sacrifices at the old shrines of their fathers. Otherwise it is hard to account for the degree of preservation of the present standing structures which would probably have all crumbled if nature had for centuries wrought destruction to the extent evident today, when everything is abandoned to the elements. The knowledge of the existence and location of the ruined cities has almost surely been a common heritage of the bush Maya, who until recent times probably had some appreciation of the fact that the stone temples, pyramids, palaces, and carved stelæ represented work of their ancestors. The writer has seen carved wooden "santos" recently placed in ruined temples by bush Indians, which well indicate the persistence of an old practice.

The culture of the Maya reached its fullest development in two periods, and in quite different areas. The Southern Maya Culture reached its apogee about 731 A.D. and declined near the end of the ninth century. The Northern Maya Culture reached its great period during the two centuries after 1263 A.D.[1]

When the Spaniards conquered Yucatan (1541), even the Northern Maya had become decadent. Seven centuries earlier, the great stone cities of the Southern Maya Culture had probably in a like manner ceased to be important centers. These southern cities were apparently abandoned, by the ruling and learned classes, about the end of the ninth century, for no stelæ are known to have been erected thereafter. Today, with the exception of Chichen Itza, Uxmal, and a

[1] The Goodman correlation as supported by Mr. J. E. Thompson is followed in this paper.

few other protected sites, all the great abandoned stone cities of both the Southern and Northern Maya lie buried and disintegrating in the wilderness. Many of them still remain unknown to archeologists.

There has been a great dearth of information about the wide gap in the central and western portions of the Peninsula, which separates the known cities of the two Maya cultures. Since 1928 I had hoped to have an opportunity to find out what might lie to the northward of Uaxactun, and to the southward of the well exploited sites of Yucatan, a region which has always been a blank space on the maps of archeologists. On the twenty-seventh of December, with El Grillo, my helper, I started for the uncharted area in the southeastern part of Campeche.

We went from Tuxpeña to Konhuas, a nearby village, where we picked up an old Indian trail leading east. Late in the afternoon we passed the ruins of the abandoned village of San Antonio. At the small village of Rio Desempeño, where we spent the night, we turned directly south on a wide open road over which chicle is hauled out by trucks during the dry season. The country through which we were passing, called the Dzequelar, has a very limited rainfall, and the all-important aguadas (surface water pools) are few and far between. This region is an immense forested plain bordered on the south, east, and west by low hills.[1] Between Rio Desempeño and Central Buenfil it contains the largest untapped area of the sapodilla forest. The Dzequelar extends from Juarez on the north to Central Buenfil in the south, and from Tuxpeña on the west to San Lorenzo and Placeres on the east, an area of over three thousand square miles.

It will be of interest to archeologists to note that there are apparently no major Maya ruins within the Dzequelar (Fig. 1) indicating that this region has never been more than temporarily and sparsely inhabited. For at least two thousand years it has probably had the same characteristics as today.

[1] The Dzequelar is one of the six major phytogeographic divisions of the Yucatan Peninsula. In a forthcoming article on the ecology of the Yucatan flora, the Dzequelar region will be described in detail.

After a difficult day's trip through akalchés (wooded swamps) and bad terrain, we reached Central Buenfil, the center of the chicle operations of Don Francisco Buenfil, the largest single chicle contractor in Mexico. Around Central Buenfil there were numerous small mounds, evidences of former habitations. Don Manuel Oscorno, the administrator, gave us additional information about the ruins which were located nearby. At dawn the next morning, the twenty-ninth of December, we headed for these ruins, going in a southwesterly direction, following a narrow muddy chiclero trail.

We soon saw many signs of former habitations. After

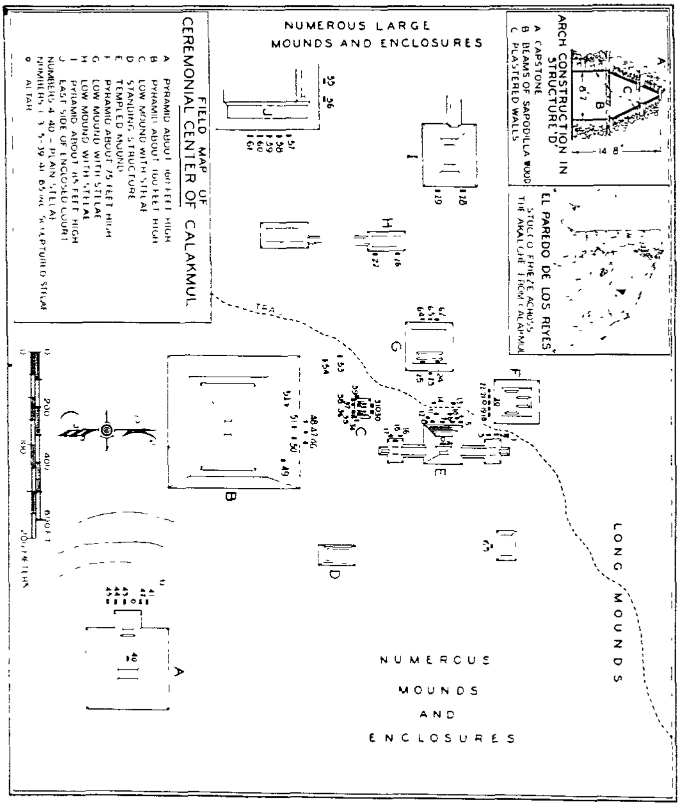


FIG. 2.—FIELD MAP OF CEREMONIAL CENTER OF CALAKMUL. Inserts: "El Paredo de los Reyes," and Arch Construction in Structure "D."

riding about seven miles, we came to rectangular and pyramidal mounds. At half past three in the afternoon I saw, standing in the trail before me, a huge sculptured monolith. We passed it, and a pyramid to our right, and entered what I found to be the main plaza and the ceremonial center of one of the most important cities of the Southern Maya Culture.

For three days we remained on the site, cutting our way from mound to mound in order to locate the various structures and monuments. Photographs were taken and everything important was charted on a field map (Fig. 2). Two great pyramids dominate the site, and these suggested the name Calakmul. In Maya, *ca* means two, *lak* means adjacent, and *mul* signifies any artificial mound or pyramid, so Calakmul is the City of the Two Adjacent Pyramids. With the help of Garcia, my guide, who had joined us at Central Buenfil, I located sixty-five stelæ, of which sixty-three were sculptured —more than ever found in any other Maya city (Figs. 3, 4, 5). While exploring through the site, I saw additional stelæ, so the total number will undoubtedly be much larger.

I climbed to the top of the highest pyramid to get a view of the great forest covering the city and the surrounding country in every direction. Calakmul stands buried in the center of a vast plain, which on the south was formerly a long lake running in a southeast-northwest direction. This silted lake is now an akalché, a swampy region where small trees and low vegetation stand in water during the wet season. This akalché is approximately thirty-six miles long, and twelve miles wide at the middle. The ceremonial center of Calakmul is situated on its northern shore, and as its whole length on both sides is covered by mounds, I venture to say that Calakmul and the communities associated with it spread out around the entire lake.

While standing on top of the pyramid at Calakmul, I discovered another very high pyramid on the far horizon. In the distance it pierces the sky as a solitary cone. This pyramid, by compass sights, lies due south of Calakmul,

FIG. 3A.

FIG. 3.—A large sculptured stela at Calakmul (number 42, Fig. 2) which is one of the finest examples of Maya art, and according to Dr. S. G. Morley was erected about 731 A.D. This stela and the other sixty-four shown in Figure 2 were discovered by the author on the twenty-ninth and thirtieth of December 1931.

FIG. 3B.

FIG. 4.—A stela (number 37, Fig. 2) with a strangler-fig tree growing on top of it. The majority of the Calakmul stelæ have been greatly damaged by such destructive agencies.

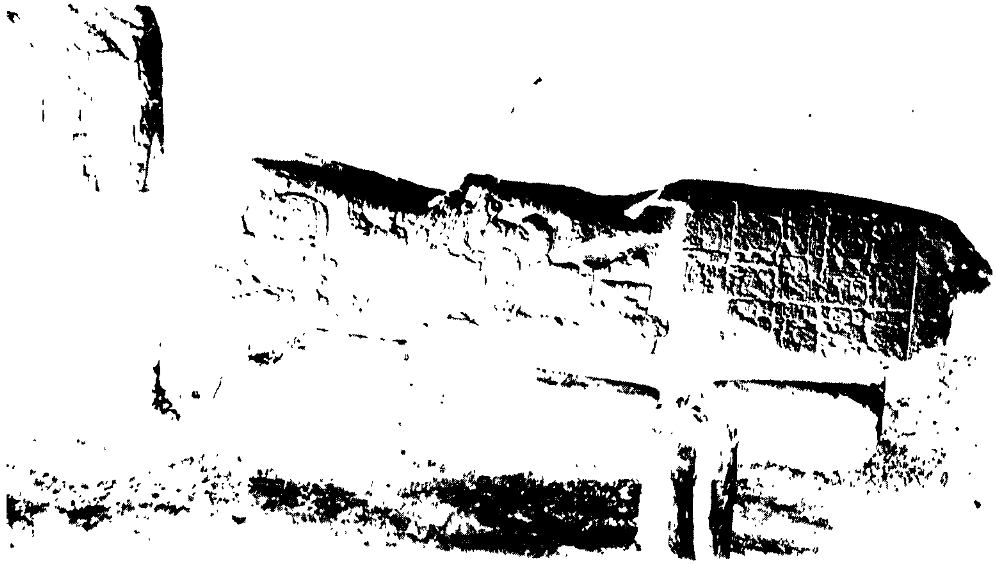


FIG. 5.—The stela of black slate (number 5, Fig. 2) is carved on all four sides. It was a monolith originally about eleven feet high which had been broken off near the center. All the other sculptured stelæ at Calakmul are of limestone, and carved on only three sides. Slate is not known to exist in the Yucatan Peninsula, so the determination of the origin of this stone is of prime importance. The source of the slate would indicate the districts between which channels of intercourse and trade existed.

within a short distance of the Guatemala border. Another lost Maya city lies buried in the jungle at its base. Later, while exploring in the Petén District of Guatemala, I learned from chicleros that this site may be the one called Lechugada.

The huge size of Calakmul, the numerous inscriptions on the sculptured stelæ, the friezes, the stucco work, as well as the great pyramids, walled enclosures, and many other structures, point to this city as one of the most important of the early Southern Maya Culture sites. Calakmul ranks with Copan, Tikal, and Palenque, heretofore regarded as the greatest cities in the southern area.

On the fifth of March I reported this discovery to Dr. Sylvanus G. Morley of the Carnegie Institution who was working at Chichen Itza. Early in April he led an expedition to the site to confirm my discovery. He wrote after his visit to the ruins:

> "Calakmul exceeded our wildest expectations. It contains the tremendous total of one hundred and three stelæ with sculptured figures and hieroglyphs, many more sculptured monuments than ever found in any Maya city hitherto known. Some of the stelæ are of high æsthetic merit, while fifty-one are dated. The site is of enormous size, and it is of the greatest archeological importance."

We left Calakmul at noon on New Year's Day, and returned to Central Buenfil, where we obtained additional pack mules and necessary provisions for a long trip.

On the third of January we headed south again. All that morning we struggled in deep mud, and early in the afternoon, after again encountering extensive mounds, we turned east, following a very torturous trail along what had been the shore of the extinct Calakmul lake. The most interesting ruined structure beside this trail is a massive wall standing three stories on top of a long low-terraced mound. The upper two stories have narrow window-like openings similar to those in the "Paloma" structure at Uxmal.

Our destination was Villahermosa, a chicle station twenty-four miles from the Guatemala border, where there is a large bush shack which would serve as a shelter for the night.

At dusk we reached the swampy water-filled east end of the lake, but had to pass as there was no place to make a camp.

On January fifth we took a trail heading south from Villahermosa. After a few hours of cutting our way through high bush, where there were numerous mounds, we came to another very large akalché where the low bush and high sedges were standing in water. The sedge leaves cut like knives, so men and animals alike were soon bleeding. From the end of the akalché we followed the southern edge of this area until four in the afternoon, when we reached a good camping site near which there were said to be ruins.

We were in high bush unlike any I had ever seen before in Campeche. Here was the border of the great Petén forest, with its luxuriant growth and giant trees and palms, which towered up more than a hundred and fifty feet. We had stopped in a *ramonal*, or grove of the breadnut tree, *Brosimum Alicastrum*. Groves of breadnut trees often contain Maya remains. Here this was also true, as I soon saw low mounds. Our camp was on high ground, and about one hundred yards south, I found a steep incline, which proved to be a natural acropolis, faced at the top by cut stones. I chopped a path through the undergrowth in the semi-darkness of the forest and came to the base of a high mound. Going around it, I made the thrilling discovery of the main plaza of another unknown city of the Southern Maya Culture. It was almost dark, so I returned to camp.

With Garcia to help cut trails I explored the acropolis the next morning. On the east (Fig. 6) there is a mound twenty feet high and three hundred and fifty feet long, on which, spaced seventy-five feet apart, stand three temples of identical size and architecture. The temples are excellently preserved, even though the centers of the massive roofs of all three have fallen and filled the rooms with rubble. This Mound of the Three Temples is flanked by two other low mounds upon the north and the south ends of the acropolis, each of which has ruins of a temple on its summit. West of the acropolis there is a great terraced pyramid rising more than a hundred feet.

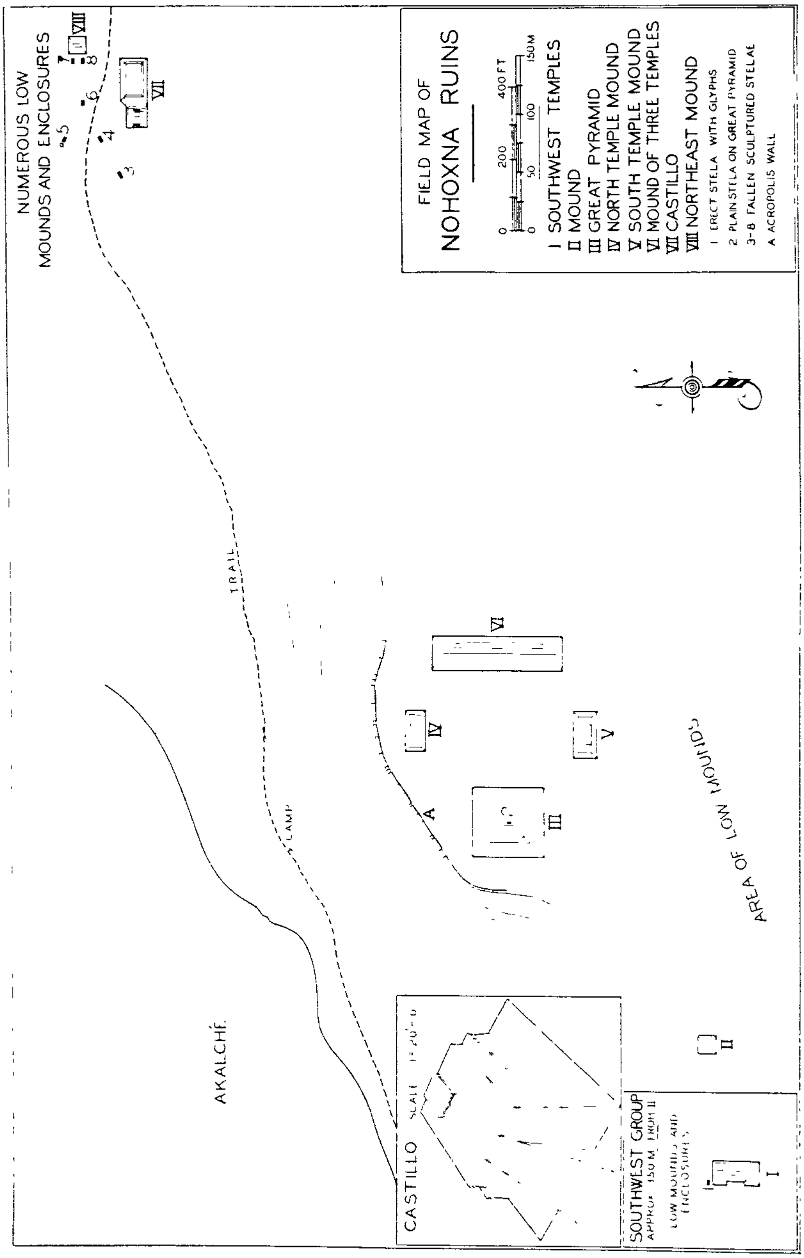


FIG. 6.—FIELD MAP OF NOHOXNA RUINS. Insert: Reconstruction of the Castillo.

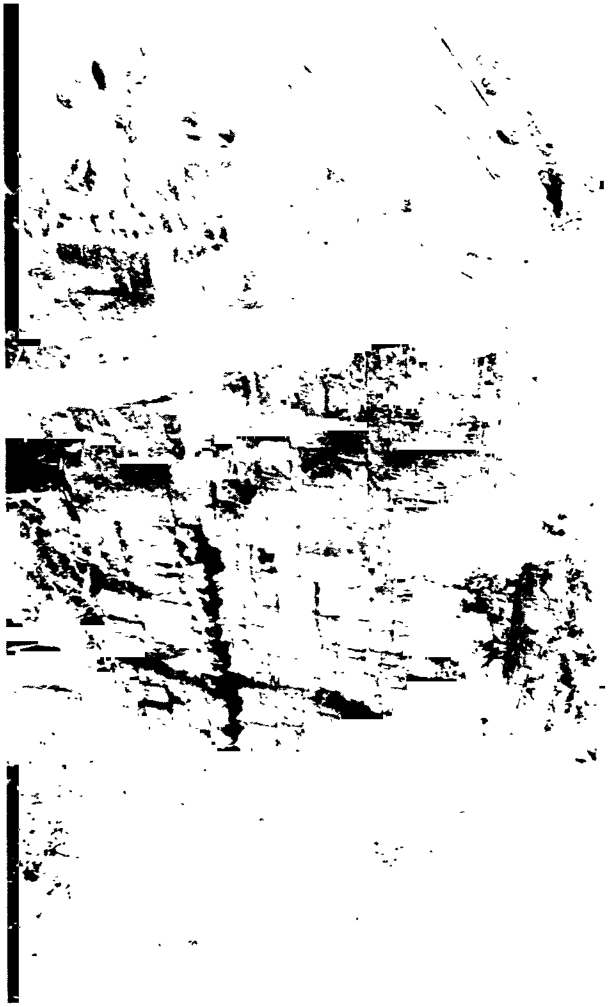


FIG. 7.—View of the lower east side of the Castillo at Nohoyna showing stone facing, cornice, and section of fallen stairway.

On top of it there stands a single monument, which, unlike others in the city, has no sculptures or hieroglyphs. This monument was probably used for making astronomical observations.

To the west of the acropolis there is another mound about forty feet high, and farther on another low one on which there are ruins of what appear to be six temples. On the northwest corner of this mound stands a dated stela.

Approximately five hundred yards east of the Mound of the Three Temples I discovered a large well-preserved "castillo," a structure of solid masonry, sixty feet square, with now fallen stairways which once ran up the east and west sides. The castillo has for its foundation a solid mound about twenty feet high, on top of which it rises twelve feet before a set-back occurs. After a set-back of four feet, it rises ten feet more to the top, which is flat. On top, at the head of the stairway on the east side, there are the ruins of a small temple (see insert, Fig. 6).

After the impressive castillo (Fig. 7), I named the city Nohoxna, meaning in Maya, a-large-well-preserved-structure. Nohoxna may therefore be called the City of the Castillo.

The cornice of the castillo is plain, and in other ways it is typical of the architecture of the Southern Maya Culture. The Maya built their temples on a sub-structure, a solid mass of rubble held together by lime mortar, faced on the outside with rectangular cut stones and covered with plaster. Today, after about fifteen hundred years, some of the plaster still remains on the walls of the castillo; and the plaster on the walls of the temples on the Mound of the Three Temples is still in good condition, although weatherworn and stained.

East of the castillo, beginning at the base of the fallen steps, is a large court surrounded by a rectangular mound fifteen feet high on top of which there are ruins, and to the northeast of the castillo, a stone's throw away, is another mound about thirty-five feet high, on the west of which are two large sculptured and dated monuments which have fallen. In this same area there are four more dated and sculptured

monuments and a round altar which line up with the monument on the summit of the Great Pyramid. I located one other monument in the plaza, bringing the total to nine, and further exploration will undoubtedly reveal many more. North of the castillo toward the *akalché* is an extensive area covered with numerous low mounds and enclosures.

Nohoxna appears to have been a great observatory where the Maya astronomers made their observations. The monument on top of the Great Pyramid forms a line to the east-northeast with the monuments north of the *castillo*, and to the west-southwest with the standing monument on the northwest corner of the mound on which the Southwest Temples stand. The monuments at each end of this line apparently mark the summer and winter solstices. The temples on the Mound of the Three Temples also could have been used as lines of sight with the stela on the Great Pyramid. Further, the four monuments and the altar north of the castillo (Fig. 6, stelæ 3, 4, 5, and 6) are so set as to form an angle that appears to be forty-seven degrees, the angle between the two solstices. It is possible that this whole city was planned as a great observatory. The natural acropolis makes it an excellent site for that purpose.

I cleared part of the top of the Great Pyramid to get a glimpse of the jungle stretching in every direction as far as the eye could see. Nohoxna stands high on the natural acropolis on the border of the Petén forest, and to the north lies the swampy *akalché* which was once a lake. Beyond this *akalché* lies the continuous bush of the Dzequelar region. Northwest on the far horizon, more than twenty miles away, lay the concealed ruins of the ceremonial center of Calakmul which I had discovered just six days before.

From the top of the Great Pyramid I could see the limits of Nohoxna. The stone ruins cover an area of about one square mile. The *castillo* and the mounds with the temples all looked like small hills covered with trees, and from above the tree tops, no one could tell that ruins lay below. The plaza was hidden from view by the giant trees.

As I stood beside the monument on the Great Pyramid, my thoughts went back to the time when this was a ceremonial center of the Maya. I pictured myself standing on this pyramid then. In front spread a panorama of hundreds of square miles covered with milpas and *acahuales*, with the sparkling clear mirror of the lake in the immediate foreground. Below, flanking the sides of the plaza, stood the five temples on high terraced mounds. Beyond the *castillo* lay the palaces of the priests and nobles—where today there remain but low mounds. Out beyond these, south, east and west of the acropolis, extended the rows of thatched-roof houses where the masses of the people dwelt, they who worked the fields, and built the temples to the gods who watched over the land.

The masses of the people certainly belonged to the agricultural group, and these were the backbone of Nohoxna as well as of Calakmul, Tikal, and the other great cities. Surrounding the stone-templed centers of the cities stood the rows of simple clean huts with their walls of mud and sticks, thatched roofs, open fires, and furnishings made of poles. Here lived the milpa makers, each one of whom had his small clearing for planting maize, the life-maintaining staple crop. The prosperity of the whole city depended upon the productivity of the milpas, for when the corn crop failed or was insufficient, the entire population faced starvation. There were no beasts of burden or means of exchange whereby food supplies could be obtained from far regions. The corn crop overshadowed all else in the struggle for existence.

With flint axes and fire, the Indians killed the bush, and planted it just as their descendants do today.[1] They also worked under the same handicaps. Crop rotation, with one chief crop, was difficult if not impossible, and in a few years the decreasing yield of corn from the same land made life precarious. Even though the planting of beans may have prolonged its productivity, the soil was eventually sapped of

[1] Thompson, J. E., The Civilization of the Mayas. Field Museum of Natural History, Anthropology Leaflet 25, 1927 (p. 13).

its fertility, the food supply then failed, and thus the inadequacy of the milpa system may have brought about the abandonment of the great stone cities just as it does with the villages of today.

The agricultural masses were occupied with their milpas during the felling, planting, growing, and harvesting season from April to October, and then they were free to work elsewhere. It is altogether reasonable to assume that the agricultural Indians devoted their time to construction work during the remaining five months of the year, that is, from November to March. The construction of the huge cities was thus accomplished by rotating the labor from milpa to building. Even as the archeologists today use Maya labor to excavate and reconstruct the ruined sites while the Indians are not working in their milpas, so the rulers of old must have used the same labor in building the great pyramids, temples, and other marvels of the Maya cities. The sculptors, painters, artists, and skilled workmen, as well as the priests, rulers, and nobles, may have devoted all their time to art, science, religion, and politics, but during the season when milpas could be worked, all others, making up the mass of the population, must have devoted their entire time to gardening and raising corn in order that the cities might survive.

In view of the fact that the very existence of the people depended on the harvests, it is not difficult to understand why the religion of the Maya masses was centered largely around agriculture.[1] The ruins of Nohoxna are but the ruins of another Maya ceremonial center where the priests made their sacrifices to the numerous gods who were believed to control the harvests, and the destiny of the people. On the stelæ they carved likenesses of their gods, rulers, priests, and warriors, and with these, the period dates along with the hitherto undeciphered hieroglyphs which possibly give the important historical facts of each epoch. The Maya set up these stelæ at periodical intervals, generally of five, ten, or

[1] Gann, T., and Thompson, J. E., The History of the Maya. New York, 1931 (p. 120).

twenty years, and from these monoliths it has been possible to trace the progressive stages in the development of design and sculpture.[1] Although they were generally set up before the temples in the main plazas, some of these stelæ were so placed as to form lines for astronomical observations.

Since Nohoxna is situated about twelve miles north of the Guatemala border on a line between Uaxactun, in Petén, and Calakmul, it is therefore also important as a connecting link between these two sites. I dare say, judging by the type of sculpture and architecture, that Nohoxna was contemporary with Calakmul. It may, therefore, have flourished as a center in the era between 500 and 850 A.D.

The preliminary exploration of Nohoxna was finished in two days, so on January seventh I made a field map of the site. A few good photographs were obtained in spite of the difficulties. In order to take a picture, it was necessary to cut openings in the high bush so that a few rays of the sun could penetrate through the forest shadows.

Early the next morning we started on the return trip to Villahermosa, where we arrived without incident early in the afternoon.

At dawn the next day, the ninth of January, we chose an old trail going west along the southwestern edge of the old silted Calakmul lake. We passed the abandoned La Fama chicle station where in a massacre in 1929 chicleros from Guatemala and Campeche fought a ghastly battle with guns and knives.

At noon after we had been continually passing mounds, I found one of the most impressive of the old Maya ruins, the Wall of the Kings.

It is a great massive wall that was at one time about ninety feet long. I could not determine its original height, but the part now standing is over twenty feet tall. It appears to have been an immense memorial monument. Lengthwise on the north and south sides it was faced with a great stucco

[1] Spinden, H. J., A Study of Maya Art. Memoirs of the Peabody Museum, Volume VI, Cambridge, Mass. 1913.

frieze, which has largely fallen except for a portion at the west end.

On each side, the lower part of this frieze is composed of five identical grotesque masks apparently representing the jaguar. The masks are each about five feet wide and three feet high, moulded of stucco in high relief, and are spaced on the monument at equal intervals. In the center of each intervening area, there is a window-like opening through the wall. On a projection extending out from the wall at the top of each of these masks, a life-sized human figure was mounted in a sitting position with legs crossed Turkish fashion. The torsos of the figures were in high relief, but the heads were made completely in the round with the face glancing downward. On the chest of each of these figures there was a breast plate in the form of a human face. All but one are in bad condition. Not long before I reached the site, a chiclero climbed to the top of the wall and, with a vandal's destructiveness, cut a deep gash with his machete across the stucco face of this one remaining well preserved figure, and also mutilated other parts of this rare piece of art. The chicleros call this monument "El Paredo de los Reyes" or "The Wall of the Kings" as the turbans on the heads resemble crowns (see insert, Fig. 2).

This wall is a meter thick and built of huge squared blocks of limestone which were covered with plaster and stucco work. The entire frieze was originally painted, as flecks of red pigment are still visible. At each end of this wall there was a full-sized human figure in stucco which from its lack of ceremonial vestments probably does not represent a ruler or a priest. This figure was in high relief, and quite unadorned, wearing only a close fitting garment. The whole frieze was well proportioned and done in a realistic manner unequaled for that type of sculpture. The base of the wall is giving away, and roots of giant trees are slowly rending the remains, so this monument will soon be no more than the usual mound of fallen cut stones, and another masterpiece of the ancient Maya will have disappeared. Nothing like this great monument has heretofore been found in the Maya land.

In another day of hard riding through almost impassable jungle along the edge of the old silted lake, we reached the end of the almost continuous ruins of the Calakmul area. We then continued west through the high forest into an area covered with high mounds, but it was not advisable to stop to investigate the site as we could not find water nearby. Exploration there may reveal important ruins, for the mounds are impressive. In order to designate this new site, I named it Multun (see map, Fig. 1), meaning in Maya, Place of the Mounds of Stone. This was the last archeological site discovered before returning to Tuxpeña by way of Esperanza, which is located on the trail that connects the interior of Campeche and the Petén District of Guatemala. Here there is a chicle warehouse. A few Indian families are the only inhabitants of this last outpost between Mexico and the Guatemala border, which is about forty miles south of that point.

Additional Sites and Explorations

While on the trip of exploration into the southeastern part of Campeche, and during the remaining month and a half that I stayed at Tuxpeña, I obtained information concerning additional unknown cities, and discovered another Maya site. I have gathered together my data on all these, and the map (Fig. 1) shows their approximate locations.

On the southwestern edge of the Los Chenes section of eastern Campeche there is a large unexplored Maya city referred to as Aurora,[1] and located about four hours riding from the old chicle station known as Reforma. By trail, this city is approximately fifty miles northeast of Rio Desempeño, but it can be reached better from Tanché, for

[1] Aurora was visited by Mr. Carlos Lopez Z. of Campeche more than thirty years ago, and the data on this ruin given herein are based largely on the description I received from him. This ruin and others in the southern Campeche area were encountered when chicle exploitation began in that region, but, as pointed out before, the knowledge of the existence of all these sites has undoubtedly been a common heritage of the bush Indians since the abandonment of the cities as cultural centers. Even though the chicleros and others connected with the chicle industry have often seen these sites, they have not comprehended their importance, and the cities have remained unknown to science.

an abandoned chicle road from the latter place goes to within a few miles of the ruin. Aurora is said to be as large as Calakmul, and to have standing stelæ, a castillo, an aguada paved with cut stones, and other structures described as similar to those of Nohoxna. It may therefore prove to be another typical city of the so-called First Empire. There are also other ruins in that area which have been seen only by hunters who could not tell how to reach them.

Placeres, a chicle station, is located about thirty-six miles (one "jornado") east of Central Buenfil. Near Placeres there is a large ruin called Misterioso by chicleros. There are said to be numerous standing stelæ. One Indian in describing it told of a temple with sealed chambers, and a chiclero said that he saw an opening at the top of a pyramid which apparently led to a tomb.

Altamira is about twenty miles north of the Guatemala border, and approximately the same distance northeast of Nohoxna. Tales regarding ruins in that vicinity are common both in Campeche and Petén. The chicleros tell of stelæ, falling temples, and high mounds.

Possibly the most interesting unexplored site may prove to be one called by the natives Tres Marias. The Indians often refer to this site as Los Tigres, a preferable name for the site when it is explored and described. There is said to be a high pyramid with steps going to the top, and at the base, at each side of these steps, two carved stone heads. These heads are called Los Tigres, the Jaguars. There are stelæ, several structures, and many mounds standing on the edge of a large *akalché* which must be crossed to reach the place.

There is also said to be a cave which must be part of that city, or else located nearby. The cave has in its mouth, standing as a guardian, an "alligator" nine feet long, carved out of a single block of limestone. In front of this "alligator," there is said to be a stela covered with "funny faces." These faces are undoubtedly hieroglyphs, and possibly record the date and other facts. The Indians say that there is a peculiar noise in this cave, so they are afraid to enter it. Several large

clay idols are said to have been removed from its entrance. This cave may be similar to the Loltun cave, and it is therefore one of the most promising places awaiting exploration.

Los Tigres is located about thirty miles southeast of Esperanza, and inasmuch as all trails into that region have been abandoned for many years, it will be difficult to find. This ruin was known to Mr. P. W. Shufeldt[1] when he was manager of the chicle operations at Tuxpeña, but there are no records showing that the site was ever carefully explored.

These sites, along with Calakmul, Nohoxna, and Multun, are the most important cities in the southeastern part of Campeche.

On the fourteenth of February I made a one day collecting trip in the Campeche "high bush" southwest of Tuxpeña near the aguada known as Bomba. Although I had continually inquired about "ruinas," no one had ever mentioned that there was a site so close at hand. To my surprise, just before reaching the aguada, which is about four miles from Tuxpeña, I encountered numerous mounds, some of which are at least twenty-five feet in height. In riding through the forest there, I discovered that this was a place of considerable extent, as mounds cover an area at least half a mile across. I did not find any carved stones or standing structures, but as a person can go within fifteen yards of a large building hidden by the dense jungle and not see it, systematic exploration there may reveal interesting remains. It would be of prime importance to know when Bomba was inhabited, for it may serve to connect Calakmul and Multun with Civiltuk, another city in northwestern Campeche.

Another small site very similar to Bomba is located within five hundred yards of Juarez, the end of the tramway line. I have heard of other small ruins in the southern and western parts of Campeche, and they may prove to be very important as connecting links between the larger cities.

[1] Mr. P. W. Shufeldt was manager of the Mexican Exploitation Company operations at Tuxpeña until 1915. He afterwards went to the Petén where he remained actively engaged in the chicle industry until 1928. While Mr. Shufeldt was at Tuxpeña, he reported the existence of Maya ruins in southern Campeche, but the archeologists failed to follow up his suggestions by carrying their explorations into that region.

Northwest of Tuxpeña, about half-way to the Gulf of Mexico, there is an Indian village called Civiltuk. At Civiltuk there is said to be a large lake in which there are reported to be islands covered with high mounds, which are rapidly being destroyed by milpa makers. It is said that carved and worked stones have been removed to the mainland, and used in the village meeting house.

It is possible that the Civiltuk ruins are those of Tayasal, the place that Maya chronicles say was settled by the Itzas after their last abandonment of Chichen Itza. This northwestern part of Campeche was the land of Chakanputun, the old home of the Itzas before their second occupation of Chichen Itza, and it would have been natural for them to return to that region. This is solely a speculation, for a site on a promontory in Lake Petén, Guatemala, has long been considered as Tayasal. The great significance of Civiltuk is that it extends the known area of Maya occupation into that region. If Civiltuk belonged to the Southern Maya Culture, then it is one of the northwesternmost cities so far reported, and indicates that all of the Campeche "high bush" region which extends west from Tuxpeña to Laguna del Carmen (Laguna de Terminos) was settled at a very early date. However, Civiltuk may have been a colony from the city of Chakanputun.

The city of Chakanputun was the great center of the Itzas for two hundred years, or from about 969 A.D. to 1204 A.D. This city was located between the present villages of Champoton and Kanasayab, and thorough exploration of its extensive, yet little known ruins will also throw much light on its history, and give needed information on the centuries which followed the fall of the Southern Maya Culture. It is probable that a study of the stelæ at Pustunich will reveal much of the history of all of that northwestern portion of southern Campeche.

It is significant to note that these discoveries fill the wide gap between the Petén cities and those of the northern part of Yucatan. From Uaxactun north, the ruins of Altamira,

Misterioso, and Aurora connect with Hochob, a well known ruin near Cibalchén, and Uxmal. This belt through the center of the Peninsula has heretofore been scientifically unexplored and unknown. Northwest of Uaxactun extending to Champoton on the coast there is the series of ruins among which Nohoxna, Los Tigres, Calakmul, Multun, Bomba, Civiltuk, and Pustunich are the most important. The discovery of these sites opens the way for systematic exploration of all the western half of the Peninsula.

Before I left Tuxpeña at the end of February I had forwarded photographs of Calakmul and Nohoxna, with details of my discoveries, to Dr. John C. Merriam, President of the Carnegie Institution. When I arrived at Chichen Itza, Dr. S. G. Morley, director of the Carnegie work there, had already received notice from Dr. Merriam of the new Campeche cities.

Since the Carnegie Institution staff, then in the field, was the logical group to continue the exploration of Calakmul and the other cities, I turned over all my photographs, field notes, maps, and other data to the Institution. Besides the data on Calakmul and Nohoxna, I also gave the Institution my maps and other information on Aurora, Misterioso, Altamira, Los Tigres, Lechugada, Pustunich, Civiltuk, and the minor ruins such as Multun, Bomba, and Juarez, all of which were unknown to archeology and the world at large.

Dr. Morley immediately realized the importance of the finds, and began making plans for a Carnegie expedition which went into southern Campeche early in April to confirm my discoveries. The general results of this expedition have already been released to the press. Calakmul proved to be a ruin of such huge size and great importance that Dr. Morley found it most profitable to concentrate all his activities at that city. The eleven other Campeche sites remain to be explored by future expeditions.

Eastern Campeche and the Petén

After conferring with Dr. Morley at Chichen Itza, I headed south again, to explore in the Petén forest of Guatemala. There was an opportunity to make a flying trip from Campeche by truck into the Los Chenes country of the eastern portion of Campeche, so between the tenth and the thirteenth of March, I visited Cibalchén. At Cibalchén I heard that there were several unexplored Maya ruins in the high sapodilla forest south of Xkanha. These sites are new, and explorations between Xkanha and Aurora may reveal new ruins of importance.

From Campeche the two routes to the Petén District of Guatemala are by water along the coast, and then up the Usumacintla River, or else overland to Tuxpeña. I chose the latter route. From Tuxpeña to El Paso, Petén, the distance by trail is approximately two hundred miles through wild, uninhabited bush where we could not expect to see a single human being after passing Esperanza. It was therefore necessary to carry all necessities which included provisions for six days and extra food for an emergency, corn for the mules, and general equipment such as tarpaulins, hammocks, mosquito nets, blankets, axes, lamps, pots for cooking, and a complete medical kit. These essentials and my personal baggage made up full loads for six pack mules. There was an arriero (muleteer) who had been over the route before, so I hired him and a helper for the trip.

We departed from Tuxpeña heading south, and the first day we reached Esperanza. That night I talked with an old Indian who told of other "ruinas" lying to the west. I had heard of these before, but I could never obtain the approximate locations of the sites. There is said to be a very high mound in one of these ruins, which is supposed to be surrounded by stone tombs. It is certain that there are old Maya cities in that area, but from hearsay it is hard to estimate the extent of the ruins. They are probably within one jornada (a day's ride) from Esperanza.

Early the next morning we departed with San Felipe, the

site of an old abandoned village, as our destination. The trail was almost closed by the encroaching bush, but as there had been some chicle traffic, it was passable. During the day we passed through Chun Cruz, a very famous akalché which is said to have claimed the lives of more pack mules than any other bajo or bog in the chicle country. The place is named after a muleteer who lost his life trying to bring a mule-train through it. It was dry at the time of our visit, so we passed easily.

Late in the afternoon we reached San Felipe, and stopped beside the aguada. Except for the acahuales (abandoned agricultural clearings), and a large grass covered area, no one could tell that the place had ever been inhabited, as no traces remain of the bush houses which once made up the village.

The next day, Easter Sunday, we started out at sunrise. No one had passed that way with mules in more than two years, so it was with great difficulty that we followed the leaf-covered trail which had never at any time been opened up. We were now in the borderland of the Petén forest. Cuts on trees, and other evidences of man's passage were often the only clues we had to follow. Needless to say, the trail was blocked by fallen trees, vines, and other jungle growth making progress slow.

Exactly at noon we came to a vine-covered stone monument, the boundary marker between Mexico and Guatemala. I would not have seen the stone if my guide had not known its location. Except for this single marker, there was no way to tell that we were passing from one country into another for all is one continuous forest. We rode three whole days more before reaching the first Guatemalan outpost, the one at El Paso, our destination.

We crossed the narrow Paixban River, and that afternoon stopped at an abandoned chiclero camp for the night. The water of the aguada was so saturated with minerals that it could not be used for cooking purposes, but there was a rain-water pool nearby from which the chicleros obtained water.

The next day we passed through another long akalché which was still muddy and made progress slow and tiring. We reached the chicle station called Isabelita at dusk. We were now in the area where chicle operations were being carried on by Guatematecan contractors, and the trails were open, yet muddy, as the sun could not penetrate through the dense crowns of the trees to dry out the forest floor.

The next day we rode hard from dawn to dusk through the great forest. Leaves of cohune palms arched the way, and mahogany, sapodilla, breadnut, and other trees towered above us. Monkeys were common everywhere. Late that evening we arrived on schedule at our destination, El Paso, without a mishap, having covered an average of thirty-five miles daily.

I did botanical work at El Paso for a month, and, while there, inquired about Maya ruins. Dr. Hector Montano N. told of one on the Rio Pasión that is inland from a place called El Choro. There are extensive mounds, at least six large standing stelæ, and a stone roadway in this site. The ruin is southwest of the city of Flores, and it can be reached in three days from there, going by way of Libertad. An additional unexplored site that is likely to prove of considerable importance is located above Piedras Negras on the Usumacintla River at another place known as El Choro. This site is inland also and apparently can not be seen from the river. Mr. John Stout of El Paso, who described it, said that it was extensive, rivaling Piedras Negras and some of the other well known cities in that region.

In the northern portion of Petén just east of the trail that I took on my way to El Paso, there is said to be a large ruin near the border, which is called Lechugada. This site may be the one that I spotted due south from the top of the pyramid at Calakmul. There are said to be other ruins in the western part of Petén, but from descriptions given by the chicleros, they are not apparently of great size.

On the twenty-eighth of April I left El Paso on my way back to the United States. I headed on muleback for Belize, British Honduras.

The first day we reached Laguna Perdida after having passed through a long bajo (akalché) after crossing the San Pedro de Martir River, and then through high forest. Laguna Perdida was the headquarters of Mr. P. W. Shufeldt when he was in charge of the chicle exploitation of the western half of the Petén. Everywhere that Mr. Shufeldt worked, he opened roads, built substantial houses, and made the places habitable. This intrepid explorer and commercial developer deserves much credit for the pioneer work that he did in Campeche and the Petén.

The second day we stopped at the village of Chiché in the savanna country, and reached San Benito on the shore of Lake Petén the next day.

Lake Petén is an extensive body of deep water several miles wide and at least fifteen miles in length. On its shores there are two large Indian villages, San Benito and San Andres, and a smaller one called Remate. The city of Flores is on an island in the west end of the lake. Its white stone buildings and the cathedral on the highest point of the island stand out in sharp contrast with the surrounding country. Flores is now in close contact with the outside world as it has weekly air-mail service.

East of Flores, within two hundred yards of the island, there is a promontory extending out into the lake on which there are high mounds. This is said to be Tayasal, the last home of the Itzas, where they settled after they left Chichen Itza when war had brought an end to the Northern Maya Culture. Tayasal is said to have remained a Maya stronghold until 1696 when it was conquered by the Spaniards.

While in San Benito and Flores, I saw in private possession a number of old Maya objects that were very interesting. There were figurines of baked clay, carved jade pieces, decorated pottery fragments, and some entire pots. These relics of the past had been found in excavations for buildings. I was struck by the many types of fragments as they ranged from crude archaic figurines to objects that post-date the Spanish conquest of 1696 (Fig. 8). In between the archaic

objects and those of post-conquest times, there was a series of figurines characteristic of the ruins of the Southern Maya Culture.

It is probable that the shore of Lake Petén and its islands have been populated continuously from prehistoric times.

FIG. 8.—Figurine from a collection in private possession at Flores, Petén.

Throughout the occupation, the inhabitants have dropped many objects such as clay idols, jade pieces, pots, vases, and figurines into the water, and as the years have passed, these things have been covered by the gradual silting of the lake. There is also the possibility that these objects were thrown into the water as sacrifices in connection with religious ceremonies.

The water level of Lake Petén has fallen considerably in recent times, so much of the village of San Benito as well as Flores is built on land that was once covered by water. Therefore these sites are excellent places to dig for stratification, which will reveal the successive occupations of that area and the culture of the people of each occupation. This important archeological work can be done very easily by digging ditches in the area that was formerly the lake bottom. Fragments and entire objects revealing the past history will be found in successive layers, the oldest buried deepest. Excavations to a depth of ten feet will probably be necessary in most cases to reach the archaic levels.

The archaic figurines indicate that the region was inhabited very early, and that the people belonged to the archaic civilization which was widespread over both continents. It is possible that the Maya developed in this country out of the archaic into their distinct civilization.

Because of the fact that the Totonac and Huaxtec tribes speaking a Maya dialect have made their home in Vera Cruz and as far north as the Panuco River, it has been conjectured that the Maya all lived in that region at one time, and that a large branch migrated south and settled at an early date the area which is now known as the Petén. The finding of the Tuxtla Statuette in Vera Cruz has been accounted for by that migration south. Inasmuch as it now appears that the Maya may have developed their culture in Guatemala and adjacent regions out of an earlier civilization, it would be more logical to conjecture that the Totonac and Huaxtec tribes migrated north away from the mother country carrying with them the culture of the south.

We had a short enjoyable visit at Flores, and at noon, the day following our arrival, we went by motorboat to Remate at the east end of the lake. Our arrieros had taken the mules around the lake by land, so when we arrived late in the afternoon, they were waiting for us.

From Remate it takes two days of hard riding to reach the border of British Honduras. Passing through high luxuriant forest all the way, we reached Yaxha the first day, and late

in the afternoon of the second day we went through customs inspection at Fallabón, the last Guatemalan outpost, and then proceeded across the border to the village of Benque Viejo, British Honduras. From here one may go to El Cayo in a Ford, and then finish the trip to the coast by boat down the Belize River.

Summary

The principal results achieved during the eight months field season of 1931–1932 may be summarized as follows:

1. Calakmul and Nohoxna were discovered, named, and called to the attention of archeologists. Calakmul ranks with the greatest cities of the Southern Maya Culture, and the sixty-three sculptured stelæ that I located there in addition to those that were plain are more than have ever been found hitherto in any Maya city. Nohoxna, built on a natural acropolis, appears to have been a great observatory as well as one of the most important early Maya ceremonial centers. Nine stelæ were discovered there.

2. The discovery of Multun and Bomba in addition to Calakmul and Nohoxna, and the location of Aurora, Misterioso, Altamira, Los Tigres, Pustunich, and Juarez fill in the open gap between the Petén cities and those of northern Yucatan. Besides these eleven ruins, information concerning several others was obtained. These discoveries and preliminary explorations in southern Campeche have opened up that vast region to detailed scientific study.

3. The discovery of the ruin (Lechugada?) south from the pyramid at Calakmul, and the gathering of information about the El Choro ruin on the Rio Pasión, and the El Choro ruin on the Usumacintla River, indicate that large unknown sites still remain in the Petén region.

4. Cultural stratification is indicated at Lake Petén and excavations there may make it possible to reconstruct much of the history of the early Maya. The archaic and other figurines indicate that this region has been continuously occupied since the time of the archaic culture. The Maya may have developed in this region out of the archaic into their own distinctive culture.

MARINE FOSSILS FROM NEW JERSEY INDICATING A MILD INTERGLACIAL STAGE

HORACE G. RICHARDS

(Read by title, January 6, 1933)

I. Introduction

A. Stratigraphy of the New Jersey Coast

The terrain adjoining the coast of New Jersey, forming the edge of the present Coastal Plain, is entirely of Quaternary age. The surface deposits along the Atlantic Ocean and continuing up Delaware Bay and River constitute what is known as the Cape May Formation. This formation varies in thickness from 40 to 50 feet (Salisbury and Knapp, 1917), and corresponds in part at least to the Talbot of Maryland (Shattuck, 1906).[1] Below the Cape May Formation and outcropping farther inland are the Pensauken and Bridgeton formations. The Talbot-Cape May Formation is thought to have been laid down during the last age in which the shore line in this region stood appreciably higher. The Wicomico-Pensauken and Sunderland-Bridgeton formations probably date from two previous ages of still higher coast lines (Antevs, 1929, p. 36). A very diagrammatic representation of a cross-section through southern New Jersey is shown in Fig. 1.

Salisbury and Knapp (1917) believed that these formations were largely of subaërial and only partly of marine or estuarine origin. However, other geologists (Shattuck, 1906; Stephenson, 1912; Cooke, 1925; etc.) hold that they or their equivalents in other states are of marine origin. Antevs (1929) favors the latter view, and points out that the absence of

[1] Recently Cooke (1930, 1931) has shown that the Talbot Formation of Shattuck is composed of two terraces at 25 and 42 feet above sea level respectively. He retains the term Talbot for the upper and uses the term Pamlico for the lower. The part of the Cape May Formation discussed in the present paper is probably roughly equivalent to the Pamlico rather than the Talbot in its newer restricted sense.

marine fossils in parts of these deposits may be due to the possibility that the mollusks and other marine animals may have been dissolved by carbonated rain water.

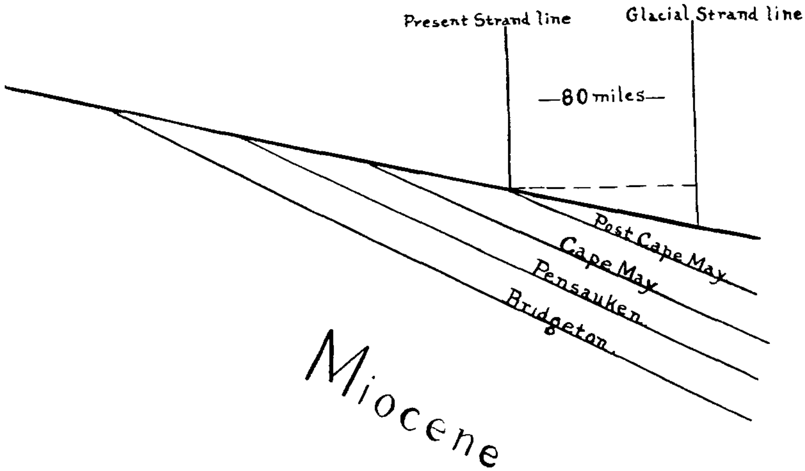


Fig. I.

Whether the Cape May Formation be entirely of marine origin or not, it is evident that at least the part near the coast was, for marine fossils have been found in the formation in this region (Cook, 1857; Shattuck, 1906; Salisbury and Knapp, 1917; etc.). All the species previously reported from the formation can be found living in New Jersey waters to-day.

Salisbury and Knapp (1909, 1917) held that the Talbot-Cape May Formation corresponded to the climax of the last (Wisconsin) glaciation. Antevs (1928, pp. 83–93) however points out that since the formation must have been at least partly formed in the sea, and since at the climax of the last glaciation the sea level was probably some 300 feet lower, and the land consequently extended some 80 miles beyond the modern New Jersey coast line, it can not well date from this stage. Antevs further calls attention to the fact that the

few fossil remains in the Talbot-Cape May Formation suggest a climate at least as genial as that of to-day, and that it consequently must have been laid down in an interglacial stage, almost surely the last (Peorian). The Sunderland-Bridgeton and the Wicomico-Pensauken are referred to the first and second interglacial epochs respectively.

The glacial dating of the Cape May Formation was based on the seeming continuity of the lower Cape May terraces with those along the Delaware River made up of the Trenton gravel, definitely of glacial age. The writer (Richards, 1932) has pointed out elsewhere that this seeming continuity may not necessarily be real, and that there might be a mingling of an older terrace (Cape May) and a younger one (Trenton) somewhere near the level of the zero isobase.

B. Paleontology

For many years shells of species no longer living in the region have been collected on the New Jersey beaches, usually after storms. (See Heilprin, 1888, pp. 19–20; Colton, 1914.) It is known that many of these species are living to-day in more southern waters. A few years ago certain real estate companies in New Jersey filled some of the marshes on the coastal islands by hydraulic dredging from the waterways back of the islands, pumping sand from about 10 to 55 feet below mean low water. The marshes were thus converted into building lots. In the sand thus pumped to the surface were many shells, crab claws, sea-urchin spines, etc. Many of the species thus uncovered do not persist in the waters of New Jersey to-day, but live in the warmer waters off the Carolinas and Florida or in the Gulf of Mexico. The deeper the hydraulic dredging, the greater is the number of southern species brought to the surface. Practically all of the species of southern shells that had previously been found cast on the beach were collected in these deposits, from which there is little doubt that they originated.

The fauna revealed by hydraulic dredging most probably was derived from the Cape May Formation, which, as indi-

cated above, underlies the coastal islands of New Jersey. The southern affinities of this fauna furnish support to the view of Antevs that the Cape May Formation was laid down during an interglacial warm stage.

The purpose of this investigation is to examine the evidence afforded by fossils belonging to this fauna collected from numerous localities.

C. *Acknowledgments*

The major part of the work was carried on while holding a Harrison Fellowship in Zoology at the University of Pennsylvania (1929–30, 1930–31). I am especially indebted to Dr. J. Percy Moore under whose guidance the work was carried out. To Dr. Henry A. Pilsbry of the Academy of Natural Sciences of Philadelphia, to other members of the staff of the Zoological Department of the University of Pennsylvania and to Dr. Frederick Ehrenfeld of the Department of Geology, I owe thanks for suggestions and criticism.

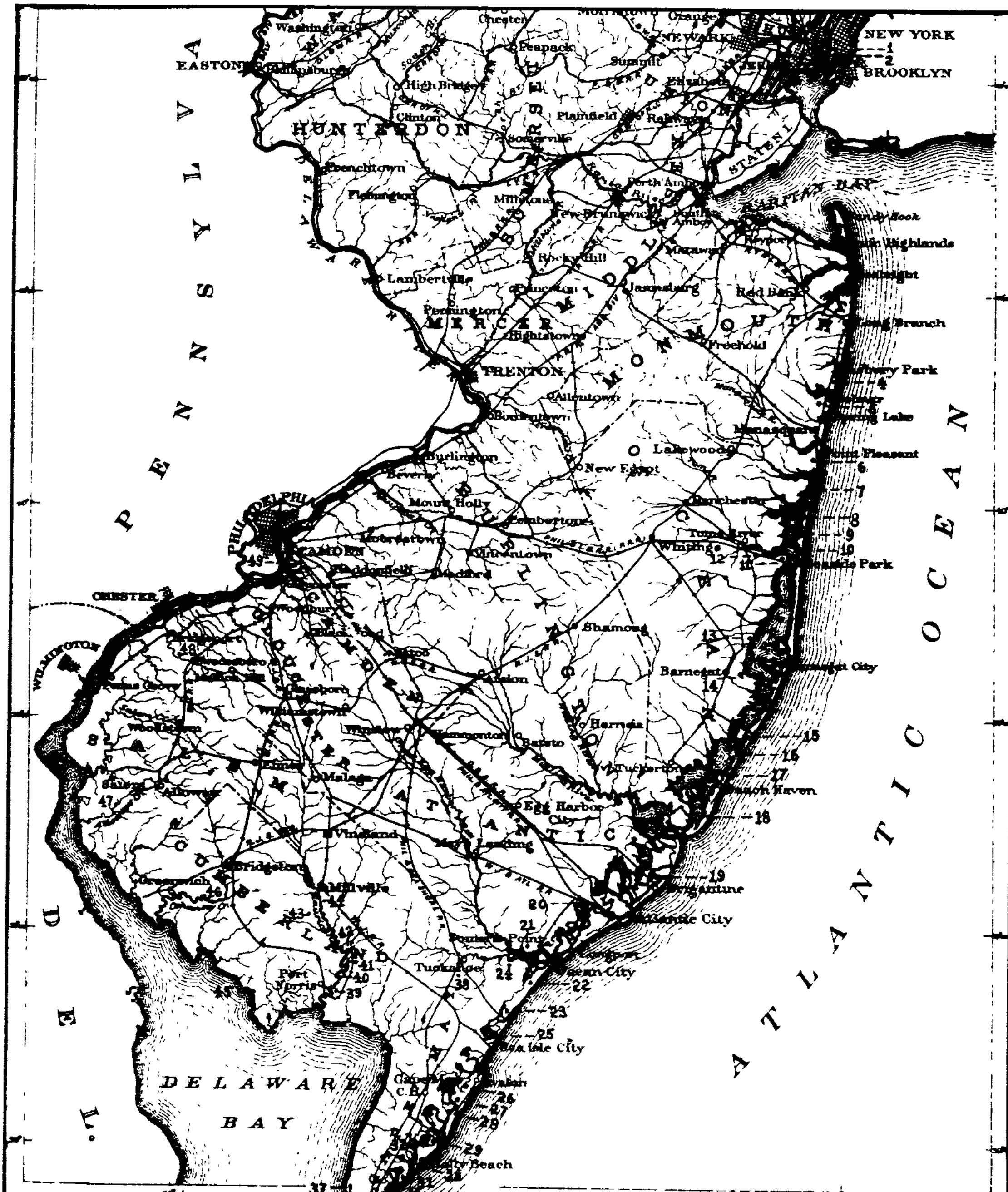
I am deeply indebted to Dr. Ernst Antevs, who originally pointed out the problem, and who has very kindly offered comments and criticism throughout the course of the investigations.

The considerable expense involved in the field work was aided from several sources. In the winter of 1929–30, I was fortunate to obtain a grant from the University of Pennsylvania through the kindness of the Provost, Dr. Josiah H. Penniman, for a winter survey of the fauna of the New Jersey coast. In the fall of 1930 the University of Pennsylvania Chapter of the Society of Sigma Xi awarded me the sum of $50.00 to help defray the expenses involved in the field work in connection with the problem.

To the United States Bureau of Fisheries I am indebted for accommodations and facilities for collecting during a visit to the laboratory at Beaufort, N. C., in February, 1930, and for collecting facilities from the station at Wildwood, N. J.

Through the kindness of Dr. Henry Fox and Mr. R. J.

PLATE I



Map of New Jersey showing localities in the Cape May Formation where fossils have been found.

Sim of Moorestown, N. J., numerous collecting trips through the state of New Jersey were arranged.

The manuscript was completed at the United States National Museum, Washington, D. C., where opportunity was granted to examine the Pleistocene material of the collections.

The following specialists have very kindly identified certain doubtful specimens: Mr. E. G. Vanatta (Mollusca), Dr. Mary J. Rathbun (Crustacea), Dr. R. S. Bassler (Bryozoa) and Dr. H. A. Pilsbry (Cirripedia).

Representative sets of material have been deposited in the Academy of Natural Sciences of Philadelphia and in the United States National Museum, Washington.

II. The Quaternary Fauna of New Jersey

A. List of Localities

Many of these localities, being composed of hydraulic fill, are of a rather temporary nature, and will probably be difficult or impossible to locate a few years hence. It is therefore thought advisable to give a rather full list of the various fossil-bearing localities within the state. Certain of these localities have been studied in detail; others have received only passing notice.

1. *New York, N. Y.* 60 foot excavation for the Federal Reserve Bank, Nassau, Liberty, Williams Streets and Maiden Lane, reported by K. V. Palmer (1923) revealed *Nassa obsoleta* and an unusually large specimen of *Venus mercenaria* cf. var. *antiqua* Verrill.

2. *Hudson River Tunnel between New York, N. Y., and Jersey City, N. J.* Thirteen species were taken from bluish mud in excavations for the Pennsylvania Railroad tunnel 90 feet below the bed of the Hudson River. The material was collected in 1906, but was only recently identified and recorded (Richards, 1930).

Numerous other fossil deposits in the vicinity of New York City, some of which are undoubtedly of Pleistocene age, have been recorded by Ross (1903), but have not been visited in the present survey.

3. *Union Beach, N. J.* Coman (1890) reports a former beach marked by low dunes, the outline of which is approximately indicated by the ten-foot contour, at Union Beach, near Keyport. It was said to have been separated from the present beach (Raritan Bay) by one-half to three-fourths of a mile of salt marsh and low upland. Considerable erosion has taken place along Raritan Bay, and in 1930 this cliff was found to be immediately beyond the present beach. Six species of mollusks were recorded from this locality.

4. *Avon, N. J.* Land on north bank of Shark River filled in by hydraulic dredging from shallow depths.

5. *Belmar, N. J.* Land on south bank of Shark River directly west of N. Y. & L. B. R.R. bridge; filled in from shallow depths.

6. *Point Pleasant, N. J.* Real-estate development "Edgewater"; filled in from shallow depths.

7. *Bay Head, N. J.* Land adjoining N. Y. & L. B. R.R. (near station); pumped from depth of 8 feet from Barnegat Bay.

8. *Deauville Beach, N. J.* Small hydraulic fill.

9. *Normandie Beach, N. J.* Hydraulic fill between Lavalette and Mantoloking.

10. *Seaside Heights, N. J.* "Sunset Island" development on Toms River Road; average maximum depth of pumping 9 feet.

11. *Barnegat Pier, N. J.* "Good Luck" development; material pumped from Barnegat Bay from depth of 5 to 20 feet.

12. *Beachwood, N. J.* Small tract of land on Toms River, property of Walter J. Mading, filled in by hydraulic dredging.

13. *Waretown, N. J.* Bay Haven Development Company; land pumped from Barnegat Bay.

14. *Barnegat, N. J.* Filled-in land at Lower Dock at mouth of a stream locally known as Horse's Neck Creek.

15. *Beach Arlington, N. J.* Filled in land on north side of Manahawkin Road; material pumped from 35 to 75 feet below the surface.

16. *Brant Beach, N. J.* Land pumped from Barnegat Bay.

17. *Beach Haven, N. J.* Beach Haven Gardens development 2 miles north of Beach Haven.

18. *Holgate, N. J.* This is a small settlement about 2 miles south of Beach Haven. About 1920 during a northeast storm the sea washed away the sand hills and beach south of this settlement and formed an inlet. According to old charts this inlet had also existed some forty years earlier (1880).

On the sand close to this inlet on August 3, 1928, were found a few very worn shells similar to some of those in hydraulic fills. It is quite possible that during the storms when the sea washed away the sand hills, some of the older deposits were exposed and redistributed upon the beach.[1]

19. *Brigantine, N. J.* Sand pumped from thorofares back of the island from a depth of from 25 to 55 feet.

20. *West Atlantic City, N. J.* Fill at real-estate development about five blocks east of P. R.R. Station at Pleasantville.

21. *Somers Point, N. J.* Development "Delray" on Mays Landing Road; material pumped from Great Egg River. Cook (1885) reports shells from wells at Somers Point and Bargaintown.

22. *Ocean City, N. J.* Filled-in land on Asbury Ave. between 20th and 21st Streets.

23. *Ocean City, N. J.* Filled-in land, Ocean City Center, 34th Street.

24. *Beesley's Point, N. J.* Cook (1857, p. 27) reported a shell marl about 5 miles south of Beesley's Point. Later (1885, p. 72) he reported three species of mollusks from excavations on Frank Stites' farm. Recent investigations suggest that this latter locality was an Indian shell pile.

25. *Sea Isle City, N. J.* Sea Isle City Gardens; sand pumped from thorofare back of island; dredging limited to 15 feet.

[1] A similar occurrence was noted at Assateague, Virginia, where the shore line has undergone considerable change in recent years.

26. *Peermont, N. J.* Land on bay side of the town; pumped from 35 feet below thorofare.

27. *Holliday Beach, N. J.* New development near Stone Harbor; sand pumped from thorofare back of island from about 15 feet.

28. *Stone Harbor, N. J.* Land adjoining the Harbor; filled in many years ago.

29. *Anglesea, N. J.* Filled-in land north of Grassy Sound Road; shallow dredging.

30. *Wildwood Crest, N. J.* In 1907 the southern end of Five Mile Beach was developed from salt marsh into an attractive summer resort (Wildwood Crest), the marshes being filled by hydraulic dredging from the channels back of the island. Some large whale bones, erroneously thought to be those of a mastodon, were dredged from Beach Creek at that time.

31. *Two Mile Beach, N. J.* In 1925, the marshes on Two Mile Beach, which was separated from Five Mile Beach by Turtle Gut Inlet, were likewise developed. Turtle Gut Inlet was closed and sand was pumped from Richardson Sound and Beach Creek (Sunset Lake) into the marshes. Sand has been taken from 30 to 60 feet below the surface.

This locality has yielded the best material of all of the localities studied. The greater extent of the development, and the fact that the work is still in progress may explain this. It is the type locality of *Milleaster (?) interglacialis* recently described (Richards, 1933).

32. *Rio Grande, N. J.* A few shells have been found in excavations on the property of Frank Mattera on the Wildwood Boulevard about a mile east of the Shore Road.

33. *Sewells Point, N. J.* A bluff some four or five feet high at the shore line was found to contain shells of the oyster and a few other species of mollusks. The sea has been eroding this beach quite rapidly during the past twenty-five years. A whale vertebra found on the beach at the foot of the cliff was possibly derived from it.

34. *Cape May, N. J.* Between Madison Avenue and Cape

May Harbor; originally marsh land separated from the beach by a row of sand dunes. Between 1903 and 1907 Cape May Harbor (Cold Spring Inlet) was dredged to make a deep water harbor. The sand beneath the bed of the harbor was pumped to the adjacent marsh land. The material was taken from some 40 to 50 feet below mean low water.

Most of the shells pumped to the surface have disappeared due to the building up of the region or to natural causes such as a dense growth of plants, but in some undeveloped parts a few species are present. A characteristic mollusk of this locality is *Astarte castanea*. Just why this species is so numerous is not clear, since it has a northern range (Nova-Scotia to New Jersey and deep water off Hatteras), and is absent from most other Pleistocene localities discussed in this paper.

35. *Cape May, N. J.* Near Coast Guard Wharf, Base 9. The shells in the sand near the harbor are fresher in appearance. They may have been more recently uncovered. Unusually large shells of *Donax fossor* are characteristic of this locality.

36. *West Cape May, N. J.* The erosion of a small cliff at the end of the boardwalk exposed a few shells.

37. *Cape May Point, N. J.* Shells and whale bones have been found in cellar excavations.

38. *Tuckahoe, N. J.* Cook (1857) says: "At Tuckahoe, casts and impressions of the common clam (*Venus mercenaria*) are found in the cemented gravel. The cementing material is oxide of iron, and no traces of the original shell are left. Some of the casts are very perfect, and being supposed by many in the vicinity to be the fleshy parts of the clam preserved they are known as 'petrified clams.' The locality where they are found most abundantly is upon the point of land between the two roads which lead from Tuckahoe, the one toward Petersburg, and the other toward Dennisville, and within a quarter of a mile of the village. They are usually within a few inches of the surface. The ground is nearly level, and 6 or 8 feet above high water."

Although no fossils were found in this locality in the

present survey, various residents of Tuckahoe remembered finding "petrified clams" while digging in yards on the Petersburg Road just southeast of the Mount Pleasant Road. A few shells found in the excavations for the high school are in the Museum at Cape May Court House, New Jersey.

39. *Heislerville, N. J.* Shell-bearing marl has been found in excavations at various places near Maurice River near the town of Heislerville. Shattuck (1906) records fourteen species (exact locality not given). Seventeen species were found in an excavation for a well on the land of Mrs. Cox (September, 1930). U. S. Geological Survey Station 2110 is Marl bed, 8 feet above tide water, Heislerville, N. J.

40. *Dorchester, N. J.* A few shells were found in a gravel bank at Penny Hill on Maurice River about two miles above locality 39.

41. *Port Elizabeth, N. J.* At Lore's Landing on Maurice River there is a gravel bank about eight feet above tide, containing a great number of oyster shells. This locality is mentioned by Cook (1868, pp. 303–4). U. S. Geological Survey Station 2109, "gravel in bed of sand on Maurice River 1 mile north of Port Elizabeth, 8 feet above tide water" is probably this locality.

42. *Port Elizabeth, N. J.* A few shells were found in the bank along Maurice River about a mile north of locality 41, in a spot formerly known as Spring Garden.

43. *Buckshutem, N. J.* A few shells were found many years ago in excavations on Charles Key's glass sand works on the west bank of Maurice River three miles south of Millville on the Buckshutem road (see Woolman, 1896). A recent visit to this and numerous other sand and gravel pits in the region has failed to disclose any additional material.

44. *Millville, N. J.* The manager of Burchem's Brick Yard on the east side of Maurice River about $3\frac{1}{2}$ miles below Millville tells me that some years ago he found some oyster shells "badly eaten away with iron rust" in excavations in his brick yard. U. S. Geological Survey Station 2108 "bed of brick clay $3\frac{1}{2}$ miles below Millville on Maurice River, about 7 feet above tide water" is probably this locality.

PLATE II

FIG. 1.—Hydraulic dredge back of Two Mile Beach, N. J.

FIG. 2.—Hydraulic Fill, Two Mile Beach, N. J.

FIG. 3.—Brigantine, N. J (locality 19).

FIG. 1.—Two Mile Beach, N. J. (locality 31).

FIG. 2.—Bluff on Raritan Bay near Union Beach, N. J. (locality 3[illegible]).

FIG. 3.—Bluff along ocean beach at Sewell's Point, Cape May, N. J. (locality 35).

45. *Fortesque, N. J.* A small portion of the marshes along Delaware Bay at Fortesque was filled during the spring of 1928, most of the material being pumped from Fortesque Creek from a depth of 8 feet.

46. *Cohansey Creek, N. J.* Cook (1857) says that shells of the common clam have been dredged several feet below the surface in digging wells near the Delaware at Fairton and Turkey Point, Cumberland County.

47. *Salem County, N. J.* Cook (1857) mentions shells in well borings in the township of Lower Alloway's Creek.

48. *Raccoon Creek, N. J.* Peter Kalm (1753) repeatedly mentions oyster shells and other remains of marine life found in excavations at the settlement at Raccoon (now Swedesboro).

49. *Philadelphia, Pa.* Salt water diatoms have been found in the Cape May Formation in the lower part of Philadelphia (see Woolman, 1890, Salisbury and Knapp, 1909). It is suggested that Philadelphia was near the margin of the marine invasion. Cypress stumps have recently been uncovered in subway excavations in Philadelphia (see Richards, 1932).

Numerous Pleistocene localities in Delaware, Maryland, Virginia, and North Carolina have been studied, but these will be discussed in a subsequent paper.

B. List of Species of All Localities Studied and Their Present Distribution

The tables on pp. 193–196 show the complete fauna, as far as the present investigations have revealed, of all marine Quaternary deposits in the state of New Jersey. It should be pointed out that not all of the localities have been studied in the same degree of detail. Certain localities where dredging had been only shallow and which a preliminary examination showed to contain a poor fauna, were studied no further.

For the sake of comparison with the recent fauna, the present geographical and bathymetric range of the species is indicated, as far as this is possible. These data were compiled largely from a study of the collections in the Academy of

Natural Sciences of Philadelphia and the United States National Museum at Washington, D. C., and from Dall's check list (1890). Unfortunately the available information on both the geographical and bathymetric distribution of the east coast fauna is far from being complete or even accurate. In the case of the mollusks there has frequently been no attempt made to differentiate between the finding of living animals and dead shells. The geographical range of certain species has been inaccurately recorded because a shell has been collected far beyond the known distribution of the living animal, where it had either been carried by the waves from its actual habitat or washed from a nearby fossil deposit. Similarly the bathymetric range has frequently been inaccurately recorded because of the dredging of dead shells in depths far greater than those from which living animals had been found. On the other hand many animals could undoubtedly be found far beyond their known limits of distribution. Therefore the accompanying table is merely an approximation and contains numerous omissions; an accurate table could be prepared only after an extensive survey of the recent fauna of our coast.

Many animals common in shallow water along the northeastern coast extend south in deeper water. Merely listing the geographical and bathymetric distribution of such species gives only an inadequate picture of their actual distribution. Again, certain species may be very abundant in certain localities, but extend far to the north or south in limited numbers. Salinity and hydrogen ion concentration may also influence markedly the distribution of marine animals.

To do proper justice to the geographical distribution of the species mentioned in this paper, it would be necessary to write a brief paragraph about each one; while this is deemed unwise, at least a partial substitution is offered by the insertion of footnotes where the mere tabular record of distribution seems inadequate.

A column indicating the presence of the species in the writer's survey of the recent marine invertebrate fauna of New Jersey is also included. Also there is a column indicating the geological distribution of the species.

FAUNA OF THE CAPE MAY FORMATION OF NEW JERSEY

	Geographical Range	Bathymetric Range (fathoms)	Earliest Geological Record	New Jersey Recent	1. New York, N. Y.	2. Hudson River	3. Keyport, N. J.	4. Avon	5. Belmar	6. Point Pleasant	7. Bay Head	8. Deauville Beach	9. Normandie Beach	10. Seaside Heights	11. Barnegat Pier	12. Beachwood	13. Waretown	14. Barnegat	15. Beach Arlington	16. Brant Beach	17. Beach Haven	18. Holgate	19. Brigantine	20. West Atlantic City	21. Somers Point	22. Ocean City (21st St.)	23. Ocean City (34th St.)	24. Beesley's Point	25. Sea Isle City	26. Peermont	27. Holliday Beach	28. Stone Harbor	29. Anglesea	30. Wildwood Crest	31. Two Mile Beach	32. Rio Grande	33. Sewell's Point	34. Cape May (Air Hangar)	35. Cape May (E. Cape May)	36. West Cape May	37. Cape May Point	38. Tuckahoe	39. Heislerville	40. Dorchester	41. Port Elizabeth (Lore's Hill)	42. Port Elizabeth (Spring Garden)	43. Buckshutem	44. Millville	45. Fortesque	46. Cohansey Creek	47. Salem County	48. Raccoon (Swedsboro)	49. Philadelphia, Pa.	Beach Wash
PORIFERA																																																						
Cliona celata Grant	Maine–Fla.			×					×											×			×			×			×	×	×		×		×		×	×	×										×					×
COELENTERATA																																																						
Astrangia danae Agassiz	Cape Cod–Fla.			×																									×	×	×				×			×	×															×
Hydractinia cf. *echinata* (Fleming)				×																															×																			×
Millaster (?) *interglacialis* Richards	Extinct																														×				×																			×
BRYOZOA																																																						
Membranipora monostachys (Busk)				×																															×																			×
Schizoporella unicornis (Johnson)				×																×				×						×						×			×	×															×
Hippoporina edax Busk	Gulf of Mexico																																		×																			
Acanthodesia sp.				×																				×											×																			×
ANNELIDA																																																						
Eupomotus dianthus (Verrill)	Cape Cod–Fla.			×																×				×	×					×				×		×																		×
CRUSTACEA																																																						
Balanus eburneus Gould	Mass.–W. I.			×	×	×																													×																			
Balanus amphitrite niveus Darwin	Mass.–Brazil			×																															×																			
Panopeus herbstii Milne-Ed.	Mass.–Brazil [1]			×	×	×																										×			×																			
Cancer irroratus Say	Labrador–S. C. [2]	0–296		×					×																										×																			
Callinectes sapidus Rathbun	N. S.–South Amer. [3]	0–23+		×																×													×		×																			
Libinia emarginata Leach	N. S.–Fla.	0–68		×																															×			×																
Libinia dubia Milne-Ed.				×																															×																			
ECHINODERMATA																																																						
Arbacia punctulata (Lam.)	Cape Cod–Yucatan			×	×	×																													×																			
Mellita quinquesperforata (Leske)	Va.–Fla.																				×									×		×			×			×																×
Spatangoid gen.?, sp.?																																			×																			

[1] Rare north of New Jersey. [2] Deeper water in southern part of range. [3] Rare north of Cape Cod.

Fauna of the Cape May Formation of New Jersey (*Continued*)

Species	Geographical Range	Bathymetric Range (fathoms)	Earliest Geological Record	New Jersey Recent	1 New York, N. Y.	2. Hudson River	3. Keyport, N. J.	4. Avon	5. Belmar	6. Point Pleasant	7. Bay Head	8. Deauville Beach	9. Normandie Beach	10. Seaside Heights
MOLLUSCA (Gastropoda)														
Acteocina canaliculata (Say)	Cape Cod–W. I.	0–63	Mio.	X										
Melampus lineatus Say	New England–Tex.	0		X										
Terebra concava (Say)	Va.–Tex.	2–49	Plio. ?											
Terebra dislocata (Say)	Va.–W. I.	2–48	Eo.											
Mangilia cerina (Kurtz and Stimp)	Cape Cod–Fla.	3–10	Plio.											
Mangilia plicosa (Adams)	Cape Cod–Fla.	0–5	Plio.											
Mangilia cf. *stellata* Stearns	Florida													
Busycon canaliculatum (L.)	Cape Cod–Gulf of Mex.	0–18	Plio.	X					X					
Busycon caricum (Gmel.)	Cape Cod–W. I.	0–10	Plio.	X										
Busycon perversum (L.)	N. C.–Gulf of Mex.	0–3	Pleist.											
Buccinum undatum L.	Arctic–N. J.	0–650												
Nassa obsoleta Say	N. S.–Fla.		Pleist.	X	X	X		X	X	X				
Nassa trivittata Say	N. S.–Fla.	0–40	Mio. ?	X		X		X	X					
Nassa vibex Say	Cape Cod–Fla.[1]	0–3												
Columbella lunata (Say)	Cape Ann–Fla.	0–12	Plio.	X										
Columbella avara Say	Mass.–Fla.	0–200	Plio.	X										
Eupleura caudata (Say)	Cape Cod–Fla.	1–3	Plio.	X										
Urosalpinx cinereus (Say)	N. S.–Fla.	0–10	Pleist.	X										
Thais hæmastoma floridana (Conrad)	N. C.–Fla.													
Epitonium lineatum (Say)	Cape Cod–Fla.	0–16	Plio.	X										
Epitonium humphreysii (Kien)	N. J.–Fla.			X										
Eulima intermedia Cantraine	Norway–W. I.	11–645												
Turbonilla conradi Bush (sp ?)														
Turbonilla interrupta (Totten) (sp ?)	N. S.–W. I.	2–107	Pleist.	X										
Scala adamsii (H. C. Lea)	Mass.–W. I.	0–20												
Cerithiopsis subulata (Mont.)	Cape Cod–W. I.	2–15												
Littorina irrorata (Say)	Mass.–Fla.			X										
Crepidula fornicata (L.)	N. S.–South Amer.	0–15	Mio.	X		X								
Crepidula plana Say	P. E. I.–W. I.	0–487	Mio.	X										
Crepidula convexa Say	N. S.–Fla.	0–22		X					X					
Polinices duplicata (Say)	Mass.–Texas		Mio.	X										

Species	11. Barnegat Pier	12. Beachwood	13. Waretown	14. Barnegat	15. Beach Arlington	16. Brant Beach	17. Beach Haven	18. Holgate	19. Brigantine	20. West Atlantic City	21. Somers Point	22. Ocean City (21st St.)	23. Ocean City (34th St.)	24. Beesley's Point	25. Sea Isle City	26. Peermont	27. Holliday Beach	28. Stone Harbor	29. Anglesea	30. Wildwood Crest
MOLLUSCA (Gastropoda)																				
Acteocina canaliculata (Say)								X												
Melampus lineatus Say					X										X	X				
Terebra concava (Say)									X			X				X	X			
Terebra dislocata (Say)												X				X	X			
Mangilia cerina (Kurtz and Stimp)																				
Mangilia plicosa (Adams)																X				
Mangilia cf. *stellata* Stearns																				
Busycon canaliculatum (L.)						X			X			X				X	X			
Busycon caricum (Gmel.)						X			X			X			X	X	X			
Busycon perversum (L.)																	X			
Buccinum undatum L.																				
Nassa obsoleta Say				X	X	X	X		X	X		X	X	X	X	X	X		X	
Nassa trivittata Say					X	X	X		X			X			X	X	X		X	
Nassa vibex Say					X	X			X			X				X	X			
Columbella lunata (Say)																X	X			
Columbella avara Say									X			X				X	X			
Eupleura caudata (Say)					X	X			X	X		X				X	X			
Urosalpinx cinereus (Say)				X	X											X	X			
Thais hæmastoma floridana (Conrad)																X	X			
Epitonium lineatum (Say)																X	X			
Epitonium humphreysii (Kien)									X							X	X			
Eulima intermedia Cantraine																	X			
Turbonilla conradi Bush (sp ?)																X	X			
Turbonilla interrupta (Totten) (sp ?)								X								X				
Scala adamsii (H. C. Lea)									X							X				
Cerithiopsis subulata (Mont.)																X				
Littorina irrorata (Say)															X	X	X		X	
Crepidula fornicata (L.)				X		X			X	X		X				X	X			
Crepidula plana Say						X	X		X			X				X	X		X	
Crepidula convexa Say					X	X	X					X				X	X			
Polinices duplicata (Say)					X							X				X	X			

Species	31 Two Mile Beach	32. Rio Grande	33. Sewell's Point	34. Cape May (Air Hangar)	35. Cape May (E. Cape May)	36. West Cape May	37. Cape May Point	38. Tuckahoe	39. Heislerville	40. Dorchester	41. Port Elizabeth (Lore's Hill)	42. Port Elizabeth (Spring Garden)	43. Buckshutem	44. Millville	45. Fortesque	46. Cohansey Creek	47. Salem County	48. Raccoon (Sweedsboro)	49. Philadelphia, Pa.	Beach Wash
MOLLUSCA (Gastropoda)																				
Acteocina canaliculata (Say)	X								X[2]											
Melampus lineatus Say	X			X																X
Terebra concava (Say)	X																			X
Terebra dislocata (Say)	X																			X
Mangilia cerina (Kurtz and Stimp)	X																			
Mangilia plicosa (Adams)	X																			
Mangilia cf. *stellata* Stearns	X																			
Busycon canaliculatum (L.)	X			X																X
Busycon caricum (Gmel.)	X				X								X							X
Busycon perversum (L.)	X																			X
Buccinum undatum L.	X																			
Nassa obsoleta Say	X		X	X	X				X											X
Nassa trivittata Say	X		X	X					X											X
Nassa vibex Say	X			X																X
Columbella lunata (Say)	X			X					X[2]											X
Columbella avara Say	X			X																X
Eupleura caudata (Say)	X			X					X[2]											X
Urosalpinx cinereus (Say)	X			X					X											X
Thais hæmastoma floridana (Conrad)	X																			X
Epitonium lineatum (Say)	X																			
Epitonium humphreysii (Kien)	X			X																
Eulima intermedia Cantraine																				
Turbonilla conradi Bush (sp ?)	X			X																
Turbonilla interrupta (Totten) (sp ?)	X																			
Scala adamsii (H. C. Lea)																				
Cerithiopsis subulata (Mont.)	X																			
Littorina irrorata (Say)	X																			X
Crepidula fornicata (L.)	X			X					X											X
Crepidula plana Say	X			X					X[2]											X
Crepidula convexa Say	X			X					X											X
Polinices duplicata (Say)	X			X					?						X					X

[1] Rare north of New Jersey.

[2] Recorded from Heislerville by U. S. Geological Survey.

FAUNA OF THE CAPE MAY FORMATION OF NEW JERSEY (*Continued*)

	Geographical Range	Bathymetric Range (fathoms)	Earliest Geological Record	New Jersey Recent	1. New York, N. Y.	2. Hudson River	3. Keyport, N. J.	4. Avon	5. Belmar	6. Point Pleasant	7. Bay Head	8. Deauville Beach	9. Normandie Beach	10. Seaside Heights	11. Barnegat Pier	12. Beachwood	13. Waretown	14. Barnegat	15. Beach Arlington	16. Brant Beach	17. Beach Haven	18. Holgate	19. Brigantine	20. West Atlantic City	21. Somers Point	22. Ocean City (21st St.)	23. Ocean City (34th St.)	24. Beesley's Point	25. Sea Isle City	26. Peermont	27. Holliday Beach	28. Stone Harbor	29. Anglesea	30. Wildwood Crest	31. Two Mile Beach	32. Rio Grande	33. Sewell's Point	34. Cape May (Air Hangar)	35. Cape May (E. Cape May)	36. West Cape May	37. Cape May Point	38. Tuckahoe	39. Heislerville	40. Dorchester	41. Port Elizabeth (Lore's Hill)	42. Port Elizabeth (Spring Garden)	43. Buckshutem	44. Millville	45. Fortesque	46. Cohansey Creek	47. Salem County	48. Raccoon (Sweedsboro)	49. Philadelphia, Pa.	Beach Wash
MOLLUSCA																																																						
(Gastropoda) *Continued*																																																						
Polinices heros (Say)	N. S.-N. C.	0-238		X																X			X												X			X					X[3]											X
Polinices triseriata (Say)	Labrador-N. C.	0-63		X																			X												X																			
Polinices lactea Guilding	Fla.-Brazil					X														X			X												X																			
Natica pusila Say	Cape Cod-Brazil	2-15		X																											X				X																			
Sigaretus perspectivus Say	N. Y.-South Amer.[1]	0-16	Plio.																																X																			X
Fissurella alternata Say	N. C.-W. I.	1-50																																																				X
Triphora sp.																																			X																			
Odostomia impressa granitina Dall.	Florida					X																																																
(Pelecypoda)																																																						
Nucula proxima Say [2]	N. S.-Fla.	2-168	Mio.	X																																							X											
Arca transversa Say	Cape Cod-Fla.	2-10	Plio.	X		X																				X				X	X				X			X																X
Arca campechiensis Gmel.	Cape Cod-South Amer.	0-10	Pleist.	X					X											X	X		X	X		X			X	X	X				X			X	X				X						X					X
Arca ponderosa Say [4]	N. C.-W. I.	2-10	Pleist.																				X												X								X											
Arca plicatura Conrad	Extinct																																										X[3]											
Ostrea virginica Gmel.	N. S.-W. I.	0-5	Mio.?	X			X	X	X		X			X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X		X		X	X	X	X	X	X		X	X[4]	X	X			X	X	X	X	X		X
Pecten gibbus irradians Lam.	N. S.-Tex.		Mio.	X				X	X		X		X	X			X		X	X			X			X				X	X				X			X																X
Anomia simplex Orb.	N. S.-W. I.	0-12	Mio.	X					X									X	X	X			X	X		X	X		X	X	X		X		X		X	X	X				X											X
Mytilus edulis L.	Arctic-N. C.	0-26+	Plio.	X		X	X		X																										X			X														X		X
Mytilus hamatus Say [5]	Cape Cod-W. I.	0-10	Mio.																																			X																
Modiola demissus (Dillwyn)	N. S.-Mexico	0-16	Mio.	X			X												X				X	X		X	X	X	X		X							X											X					X
Crassinella lunulata (Conrad)	Mass.-Fla.		Mio.																	X																																		
Cardita borealis (Conrad) [2]	Arctic-N. C.	5-190	Mio.	X																X	X																		X															
Astarte castanea (Say) [2]	N. S.-N. C.	5-190	Pleist.	X																X																			X															
Divaricella quadrisulcata (Orb.)	Mass.-South Amer.	7-54	Mio.																	X			X							X	X				X			X																X
Cardium mortoni (Conrad)	N. S.-Brazil	0-50	Mio.?	X															X	X															X			X																
Venus mercenaria L.	Gulf of St. L.-Mexico	0-12	Mio.	X	X		X	X	X		X		X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X		X		X	X	X	X	X			X	X	X			X			?	X	X		X
Venus campechiensis Gmel.	Cape Cod-Mexico	0-12	Mio.	X					X										X	X			X			X			X		X				X			X																X
Chione cribaria (Lam.) (?)	Hatteras-Cen. Amer.	15-124	Mio.																																								X[4]											
Callocardia morrhuana (Linsley)	P. E. I.-Florida	2-63		X																																																		X
Gemma gemma (Totten)	Labrador-Fla.	0-25		X															X	X		X	X												X								X											

[1] Rare north of New Jersey. [2] Local and in deep water south of New Jersey. [3] Recorded from Heislerville by U. S. Geological Survey.
[4] One record from Massachusetts. [5] Rare north of Virginia.

Fauna of the Cape May Formation of New Jersey (*Continued*)

	Geographical Range	Bathymetric Range (fathoms)	Earliest Geological Record	New Jersey Recent	1. New York, N. Y.	2. Hudson River	3. Keyport, N. J.	4. Avon	5. Belmar	6 Point Pleasant	7. Bay Head	8. Deauville Beach	9. Normandie Beach	10. Seaside Heights	11. Barnegat Pier	12. Beachwood	13. Waretown	14. Barnegat	15. Beach Arlington	16. Brant Beach	17. Beach Haven	18. Holgate	19. Brigantine	20. West Atlantic City	21. Somers Point	22. Ocean City (21st St.)	23. Ocean City (34th St.)	24. Beesley's Point	25. Sea Isle City	26. Peermont	27. Holliday Beach	28. Stone Harbor	29. Anglesea	30. Wildwood Crest	31 Two Mile Beach	32. Rio Grande	33. Sewell's Point	34. Cape May (Air Hangar)	35. Cape May (E. Cape May)	36. West Cape May	37. Cape May Point	38. Tuckahoe	39. Heislerville	40. Dorchester	41. Port Elizabeth (Lore's Hill)	42. Port Elizabeth (Spring Garden)	43. Buckshutem	44. Millville	45. Fortesque	46. Cohansey Creek	47. Salem County	48. Raccoon (Swedesboro)	49. Philadelphia, Pa	Beach Wash
MOLLUSCA																																																						
(Pelecypoda) *Continued*																																																						
Transenella stimpsoni Dall.	N. C.-Fla.	3-32	Plio																																																			X
Petricola pholadiformis Lam.	N. S.-Brazil	0-18	Pleist.	X									X						X	X			X	X					X		X				X			X	X				X											X
Tellina tenera Say	P. E. I.-Gulf of Mexico	0-80	Plio.	X																X													X		X																			
Macoma balthica (L.)	Arctic-Georgia	0-187	Pleist.	X					X											X											X																							
Cumingia tellinoides (Conrad)	Cape Cod-W. I.	0-50	Mio.																																								X											
Abra æqualis (Say)	N. C.-W. I.	0-49	Mio.			X																																																
Donax fossor Say	N. Y.-Fla.		Mio.	X																X			X							X	X		X		X			X																X
Ensis directus (Conrad)	Labrador-Fla.	0-25	Eo.	X					X				X	X			X			X	X		X			X					X		X		X			X					X											X
Tagelus gibbus (Spengler)	Mass.-W. I.		Mio.	X				X	X				X					X	X	X			X	X			X		X		X				X			X	X															X
Mactra solidissima Dillwyn	Labrador-S. C.	0-16	Mio.	X			X						X						X	X			X			X					X		X		X		X	X																X
Mactra lateralis Say	N. B.-W. I.	0-60	Mio	X		X			X											X											X		X		X			X					X											X
Rangia cuneata (Gray)	Gulf of Mexico-W. Fla.		Plio.																																			X[1]																
Labiosa canaliculata Say	N. J.(?)-South Amer.		Pleist.																																X																			X
Mya arenaria L.	Cape Cod-S. C.	0-100(?)	Plio.	X			X	X	X				X		X		X																		X														X					X
Corbula contracta Say	Mass.-W. I.	3-63	Plio.	X															X		X														X			X					X											
Saxicava arctica (L.)	Arctic-W. I.	0-100	Mio																																X																			
Pholas costata L.	Cape Cod-South Amer.		Plio.	X																																																		X
Pholas truncata Say	Mass.-Texas			X																	X		X							X	X				X																			X
Monticuta bidentata (Mont.)																																											X											
VERTEBRATA																																																						
(Elasmobranchi)																																																						
Myliobatis sp.																																			X																			
Lamna sp.																																			X																			
Prionotus sp.																																			X																			
(Pisces)																																																						
Spheroides sp.																																			X																			
(Mammalia)																																																						
Balænoptera physalus L.				X																														X	X		X				X													
Odicoileus sp.																																			X																			

[1] Well boring, Cape May (Woolman).

C. Notes on the Quaternary Fauna of New Jersey

PROTOZOA (Foraminifera)

Dr. Joseph A. Cushman kindly identified a few specimens of Foraminifera from Two Mile Beach (locality 31). The following genera were represented: *Nonion*, *Elphidium*, *Rotalia*, *Quinqueloculina* cf. *seminulum* and *Trochamina*.

The microscopic fauna of the region has not been studied in these investigations.

PORIFERA

Borings of the Sulphur Sponge (*Cliona celata*) have been noted on shells from practically all localities studied.

COELENTERATA

Pieces of *Astrangia danæ* are present in many of the localities studied. This coral, while living off New Jersey to-day, is rather rare.

Several specimens of a *Hydractinia*, probably the recent species *H. echinata*, have been found at various localities and cast up on the beach.

Milleaster (?) *interglacialis*, recently described as new (Richards, 1933), has been found at localities 27 and 31.

BRYOZOA

In addition to a few common encrusting species of Bryozoa, there are a few forms worthy of special mention. *Hippopœdra edax* which was found encrusting a shell at Two Mile Beach (locality 31) lives to-day in the Gulf of Mexico, and is known from the Miocene of North and South Carolina and the Pliocene of South Carolina (Canu and Bassler, 1928, pp. 139–40).

A rather common form encrusting the shells of *Pholas costata* and several other mollusks has been placed in the genus *Acanthodesia* cf. *savartii* by Dr. R. S. Bassler, who has examined the bryozoa specimens.

ANNELIDA

Calcareous tubes of *Eupomotus dianthus* (= *Hydroides dianthus*, *Serpula dianthus*) have been found on clam shells in many of the localities.

ECHINODERMATA

Broken tests of the sand dollar (*Mellita quinquesperforata*) have been found in many of the localities. Perfect bleached individuals have been found on the flat outer beaches at Two Mile Beach, Avalon, etc. The species is not known alive north of Virginia.

Spines and occasionally a broken piece of the test of *Arbacia punctulata* have been found at a few localities and spines of a Spatangoid have been found at Two Mile Beach.

MOLLUSCA

Eighty-one determined species of mollusks have been taken from the Quaternary deposits of New Jersey. With a few exceptions they are all south-ranging species, or are practically equally distributed north and south of New Jersey to-day. A few of the north-ranging forms which are exceptions to the above statement have been found only washed upon the beach, and it is suggested in a later section of this paper that they were derived from a glacial deposit laid down off shore some distance beyond the present shore line.

A few north-ranging forms have been found in the various deposits throughout the state. In this category are: *Polinices heros*, *P. triseriata*, *Cardita borealis*, *Astarte castanea* and *Mya arenaria*. All of these species have their southern limit a short distance south of New Jersey.

The remaining species may be regarded as south-ranging or at least as occurring alive a considerable distance south of New Jersey. Of these thirteen are known in the living fauna only from the coast south of New Jersey. These are: *Terebra concava*, *T. dislocata*, *Busycon perversum*, *Polinices lactea*, *Sigaretus perspectivus*, *Thais hæmastoma floridana*, *Fissurella*

alternata, *Mangilia stellata*, *Arca ponderosa*, *Labiosa canaliculata*, *Transenella stimpsoni*, *Rangia cuneata*, *Odostomia impressa* var. *granitina* and *Chione cribaria*.

Of the remaining, twelve species have not been found alive in the region although they have been reported both north and south of New Jersey. The writer has made a rather thorough survey of the recent fauna of New Jersey, and if present at all, these species must be exceedingly rare. Some are quite abundant in the deposits. In this group belong: *Mangilia cerina*, *M. plicosa*, *Nassa vibex*, *Seila adamsii*, *Turbonilla interrupta*, *Cerithiposis subulata*, *Eulima intermedia*, *Triphora* sp., *Cardium mortoni*, *Divarcella quadrisulcata*, *Mytilus hamatus* and *Abra æqualis*.

CRUSTACEA

Numerous crab claws were found at many of the localities; these were identified by Dr. Mary J. Rathbun as: *Panopeus herbstii*, *Cancer irroratus*, *Callinectes sapidus*, *Libinia emarginata* and *L. dubia*.

A few specimens of barnacles (*Balanus eburneus* and *B. amphitrite niveus*) have been found at various localities.

CHORDATA

Among some fragments of fish bones collected at Two Mile Beach (locality 31) were recognized pieces of the dental plate of *Myliobatis*, teeth of *Lamna* and pieces of *Spheroides* and *Prionotus*. While it is probable that this material is from the Pleistocene deposits, it is, of course, possible that it may be of recent age and overlying the Pleistocene beds.[1]

A good deal of publicity was aroused several years ago (1907) over the finding of the remains of a "mastodon" in the dredgings in Beach Creek (now Sunset Lake) in the development of Wildwood Crest (locality 30). These bones were found by the Baker Brothers, the founders of Wildwood and Wildwood Crest, and were exhibited both in Philadelphia and Wildwood.

[1] Identifications by Dr. C. W. Gilmore and Mr. B. A. Bean.

I was recently able to locate some of these bones, and upon examination found them to be none other than the remains of a whale, probably the Finback (*Balænoptera physalus*).[1]

At the cliff at Sewells Point (locality 33), Frederick F. Rockwell, Jr. and the writer found a caudal vertebra of a fairly large Finback Whale. The sea had been eroding the cliff quite rapidly at that time, and it is thought probable that the bone had become uncovered from the cliff. The presence of a rather thick deposit of calcium salts on the centrum suggests that the bone is of considerable age.

Mr. Stanley Rushton of Wildwood, N. J., recently showed the writer a piece of whale vertebra that he found close to the present filling operations on Two Mile Beach (locality 31). This bone and the ones found by the Baker Brothers are highly mineralized, and it is suggested that they may belong to the Pleistocene synchronous in age with the mollusks dredged in the same locality, although it is possible that the bones are merely those of a recent whale which had become buried in the Pleistocene formation.

A small piece of a bone of a deer (*Odicoileus*) was found at locality 31.

III. Correlation of the Pleistocene Deposits of the Atlantic Coastal Plain, and the Age of the Warm Fauna Described from New Jersey

A. North of the Terminal Moraine

It is difficult to correlate Quaternary marine deposits north of New Jersey with those within the state and southward. The immense ice sheets which covered the New England states have completely altered the appearance of the Pre-Wisconsin formations. Also the land north of the terminal moraine was lowered considerably in Wisconsin time due to the great pressure of the ice causing the sea to invade the land; this was probably not true, or at least not true to the same extent, south of the terminal moraine.

[1] Identification verified by Dr. Remington Kellogg.

Quaternary fossils are reported from Labrador and Maine (Packard, 1865; Clapp, 1907; Perkins, 1927; Antevs, 1928a, and others), but these probably date from the last glaciation or from postglacial time. The species are largely of northern distribution and resemble the fauna of that region to-day. They also bear a resemblance to fossils from southern Greenland.

Stimpson (1851) lists fourteen species of shells from the Quaternary of Point Shirley, Mass., about 50 feet above high water. They are all to be found living in Massachusetts waters to-day.

According to Hörner (1929, p. 141): "When the region was released from the ice, the shore line in northeastern Massachusetts lay higher than at present. It withdrew rapidly to below the present stand, reaching in the Boston region at least the level of minus 43 feet. Finally it transgressed to its present position." Shimer (1918) records some dark gray silt with rich molluscan fauna resembling that now living off the coast of Virginia, some 13 to 15 feet below the surface level of Boylston and Berkeley Streets, Boston. The stand of the shore line this far below that of the present time, together with the presence of the warm water fauna, is taken to indicate that the deposit was laid down at the time of the postglacial temperature maximum. There is considerable evidence favoring the recognition of this phase, sometimes spoken of as Atlantic Time, especially from work done in Europe. (See Antevs, 1928b.) This stage probably occurred from 7000 to 3000 years ago (Antevs, 1928, 1928b, pp. 559–560).

The fossils from the coast of Maine, Point Shirley and Boston no doubt date from the postglacial stage when the shore line was farther inland than at present and therefore can not be correlated with the fossils from New Jersey and the south.

Hörner (1929) found no trace of a postglacial invasion of the sea south of Boston, and therefore we may consider any marine fossils found south of this point as belonging to an older period.

At Sankaty Head, Nantucket, Mass., there are fossiliferous beds that were recorded as early as 1849 by Desor. Since that time various studies have been made, probably the most complete being that of Cushman (1906). The beds at Sankaty can be divided into an upper and a lower layer, each in turn being composed of two parts. The lower layer contains fossils of southern distribution, while those of the upper layer are of northern range. Fuller (1914, p. 220) places the Sankaty beds in the second (Yarmouth) interglacial stage.

Sanderson Smith (1867) lists some twenty-seven species of Quaternary marine mollusks from Gardiner's Island, N. Y. The deposit has a northern aspect. Fuller (1914, pp. 114, 220) correlates this deposit with the one on Nantucket, placing them near the end of the Yarmouth interglacial stage.

Pleistocene marine mollusks and other remains have long been known from the St. Lawrence River Valley and Lake Champlain (see Fairchild, 1919). It was supposed that the sea in late glacial times extended up the St. Lawrence River joining Lake Champlain. Recently (1922) Goldring has presented evidence suggesting that while marine conditions existed in the St. Lawrence region, Lake Champlain was brackish and the northern Hudson River was fresh. No marine fossils were reported south of Crown Point, N. Y. to Storm King (Goldring, 1922).

In late glacial time the mouth of the Hudson River lay far out on the continental shelf, and no salt water reached inside a line from Sandy Hook to Coney Island to Long Island (Antevs, 1928, p. 86). Only much later, probably in post-glacial time, did salt water extend up the Hudson, marine mollusks being known up to Storm King, 50 miles north of New York City (Goldring, 1922).

Deep excavations (60–90 feet) in the vicinity of New York City[1] have revealed a fauna suggesting a warm climate (Richards, 1930). It is quite probable that these represent

[1] Locality 2 of present paper.

an earlier invasion of the sea, perhaps during the last (Peorian) interglacial stage.

B. South of Terminal Moraine

South of the terminal moraine it is somewhat easier to correlate the fossiliferous horizons. On the Atlantic seaboard south of New York there is a series of terraces composed mostly of sand, gravel and clay. These terraces are frequently limited upward by a bluff from which they slope toward the sea. As mentioned in the introduction there is some question as to whether they are of marine or fluviatile origin, but the usual opinion is that they are at least partly marine (see Antevs, 1929, pp. 35–37).

Antevs (1929) attempts to correlate the terraces which have been described from the various states. In the case of the youngest, he correlates the Cape May of New Jersey, the Talbot of Maryland (and Virginia), the two terraces Pamlico and Chowan of North Carolina, the Satilla of Georgia and the two terraces Pensacola and Tsala Apopka of Florida, suggesting that they all date from the third (last) interglacial stage.

More recently Cooke (1930, 1931) has reviewed the coastal terraces of the Middle and South Atlantic States and has arrived at a somewhat similar correlation of terraces. However, he points out that the Talbot formation of Maryland is really made up of two terraces, 25 and 42 feet above sea level, equivalent to the Pamlico and Chowan of North Carolina. He refers the younger of these terraces to an inter-Wisconsin warm stage and the older to the Peorian (last) interglacial stage.[1] Both Cooke and Antevs assume glacial control of sea water as a cause of terracing.

In practically all cases the fossils from the youngest Pleistocene terrace of the Atlantic Coastal Plain, thus far reported, suggest a milder climate than the present; this is

[1] An "inter-Wisconsin warm stage" probably can be taken as an equivalent of an interglacial stage. The Pleistocene of North America has not yet been completely divided into its various stages. Leverett (1929) recognizes an inter-Wisconsin warm

further evidence of the contemporaneous deposition of the terraces and for an interglacial dating.

A large number of species have been reported from the Talbot of Maryland, especially from two localities in St. Mary's County, Wailes Bluff and Langley's Bluff (Shattuck et al., 1906). There is a striking similarity between Shattuck's list and the list from the Cape May reported herein, although there are more warm water fossils in the New Jersey deposits. Smith (1920) and Mansfield (1928) have divided the Wailes Bluff locality into various zones.

Similar warm water fossils have been reported from the youngest terrace in Virginia, North Carolina and South Carolina (Clark and Miller, 1912: Stephenson, 1912; Mansfield, 1928; Pugh, 1905).

In Florida fossils have been found at numerous places in the youngest terrace, including the much discussed locality, Vero, where human remains have been found (see Cooke and Mossom, 1929, etc.). The human remains may or may not date from the interglacial stage (see Berry, 1917; Chamberlain, 1917; Hay, 1928; Hrdlička, 1917; Sellards, 1917, etc.).

Additional localities in Delaware, Maryland, Virginia and North Carolina will be discussed in a subsequent paper.

C. The Age of the Mild Fauna from New Jersey

From the previous discussion we find that there was a late Quaternary invasion of the sea north of Boston from which most of the shells reported from northern New England probably date. It is quite probable, however, that there are

stage, but this is not recognized by Antevs (1931). The accompanying table shows the divisions of the Pleistocene as usually accepted.

Glacial Stages	*Interglacial Stages* *Postglacial Time*
5. Wisconsin	
	4. Peorian
4. Iowan	
	3. Sangemon
3. Illinoian	
	2. Yarmouth
2. Kansan	
	1. Aftonian
1. Nebraskan	

traces of an interglacial invasion of the sea to be found in New England (as Sankaty Head, Nantucket) that have been overlaid and perhaps mixed with deposits of glacial age. The warm water fauna found at Sankaty Head and in the deposits of New Jersey would not be expected to extend north of Cape Cod, assuming that the positions of the Gulf Stream and Labrador Current were approximately the same as to-day.

South of the terminal moraine correlation is less difficult. The terraces of Florida, Georgia and North Carolina have frequently been correlated, as have those of Maryland, Delaware and New Jersey. Antevs (1929) sees "no serious objection to a correlation of the terraces north and south of Hatteras," and as has been mentioned above, dates the most recent of these from the last interglacial stage.

Therefore it seems most probable, as mentioned in the early part of the paper, that the mild fauna in question is derived from the Cape May Formation, and dates from the last interglacial stage. However, it is possible that part of the material may have been derived from the underlying Pensauken formation dating from the second interglacial stage. Strock (1929) has shown that there was a marine invasion in Pensauken time, and Woolman (1899) has reported marine diatoms from this formation.

It is also possible that another part of the fauna may date from the warm postglacial stage (see Antevs, 1925), although no postglacial marine invasion has been demonstrated in New Jersey. Hörner (1929) believed that the postglacial sea had not invaded the land south of Boston.

A study of the records from well borings at various parts of New Jersey adds some information on the dating of the faunas. A rich diatomaceous deposit was found at Wildwood, N. J., at the depth of 78–180 feet. The deposit contained remains of both freshwater and marine species and was especially characterized by the presence of *Polymyxus coronalis*, a form found at the mouth of rivers in South America (Boyer, 1895). Woolman (1899) found the same diatomaceous deposit at Rock Hall, Maryland, and suggested that it belonged to the Pensauken.

Woolman (1895, 1896) records a diatom bed which underlies the part of New Jersey which is less than 45 feet above tide. At the shore-line of southern New Jersey it averages 29–46 feet below the surface; at Absecon, 7 miles inland from Atlantic City, it is at tide level (or a few feet below); at Bridgeton and Mays Landing it is above sea level. He states that this bed is probably correlated in age with a diatomaceous deposit of clay underlying the portion of Philadelphia having an elevation of 25–40 feet (no higher) containing freshwater and marine species. It seems quite reasonable to suppose that this diatom bed is part of the Cape May Formation, from which the fossils discussed in this paper were probably derived.

Woolman (1903) records a bed of black clay at 52–62 feet below the surface at Cape May, N. J., containing what he calls "northern mollusks," and below this (62–85 feet) a greenish clay containing "southern mollusks." His "northern mollusks" are *Pholas costata* and *Gemma manhattensis* (= *Gemma gemma*), both of which are now known to extend considerably south of New Jersey. His "warm water fauna" is more interesting. *Rangia cuneata*, now restricted to the Gulf of Mexico, is recorded therein. The two deposits probably belong to the Cape May Formation, overlying the rich diatomaceous layer referable to the Pensauken. The finding of *R. cuneata* in the deeper part of the well drilling, together with the presence of a greater percentage of southern species in the deeper hydraulic dredgings, seems significant.

IV. European Interglacial Fauna

In Europe considerable work has been done on the various glacial and interglacial deposits. Danish geologists who have made a very thorough study of these beds recognize three Pleistocene glaciations corresponding to the last three of the four glacial epochs distinguished in the Alps, the Mindel, Riss and Würm (Madsen et al., 1928, p. 86). The Eem deposits of southwestern Denmark, adjacent Germany, Prussia, Holland and Belgium have been extensively studied and are

referred to the last interglacial stage, the same as the Cape May (Madsen, Nordman and Hartz, 1908; Nordman, 1928; Madsen et al., 1928).

The Eem fauna probably indicates a mild climate such as now prevails on the west coast of France or in the Mediterranean (Madsen, Nordman and Hartz, 1908, pp. 154–160, 284–286; Nordman, 1928, p. 57).

V. The Climate Indicated by the Fauna

The importance of mollusks as indicators of climate has been brought out quite clearly in a study of the Quaternary shell beds in Scandinavia (Antevs, 1928b). The present study of the fauna of the Cape May Formation of New Jersey seems to suggest a milder climate than that existing in the region to-day. From a study of the modern northern limits of the mollusks of the formation (see pp. 193–196), one might suppose that a climate comparable to that of Cape Hatteras to-day existed in New Jersey during the warmest part of the last interglacial stage. However, the New Jersey material suggests a variation in the climate during the interglacial stage. As mentioned before, the fossils from the deeper (hence older) part of the formation indicate a warmer climate than that existing to-day, while those in the upper (younger) part indicate a climate similar to that of to-day. It seems significant that the deeper the hydraulic dredging, the greater is the number of southern species pumped to the surface. This is consistent with the view that the Cape May Formation was laid down during an interglacial stage and the presence of the colder water fossils in the upper part of the formation may indicate that the climate was becoming colder due to the approaching glaciation.

A study of fossil pollen from interglacial bogs in Europe suggests that the climate fluctuated in the same manner (Jessen and Milthers, 1928, pp. 334–369). A similar fluctuation is indicated by the marine shells of the Eem deposits (Madsen et al., 1928, pp. 88–107). Little or nothing seems to be known about the climate in America during the last interglacial stage (Baker, 1920, p. 360).

Undoubtedly with the approach of the glacier from the north an Arctic fauna invaded the waters at least as far south as New Jersey. As the ice sheet extended, sea level probably lowered, and at the climax, according to Antevs, was some 300 feet lower and the shore line was 80 miles farther east than at present. Consequently any remains of life in this period would have been laid down at the bottom of the sea some distance off the present shore line of New Jersey.

Very worn shells of *Buccinum undatum*, *Neptunea decemcostata* and *Colus gracilis* have occasionally been found on the beaches of New Jersey. These are all of northern distribution, and with the exception of *B. undatum* reported from deep water off New Jersey, have not been found alive in the coastal waters of the state.[1]

The extinct gastropod, *Neptunea stonei* (Pilsbry), described by Pilsbry (1893) is known only as a fossil from the beaches of New Jersey, from a Miocene (?) deposit on Martha's Vineyard (Dall, 1894) and from a Pleistocene deposit on Nantucket which may date from the glacial period. During the past few years a few shells of this species have been found on the beach at Cape May, N. J., usually after a heavy sea. Other species of *Neptunea* closely resembling the extinct *N. stonei* are common in Arctic waters. It is quite possible that these species belong to a deposit laid down at the bottom of the sea during a glacial stage some distance off the present coast, and that they are occasionally carried to the shore by the action of waves and currents.

VI. A Possible Explanation of the Warm Water off New Jersey During the Last Interglacial Stage

It is evident that in Cape May time at least part of the present New Jersey shore was submerged. A similar condition is indicated along the shores of Maryland, Virginia and North Carolina in the probably synchronous formations. Even a very slight submergence along the shore of North

[1] *Buccinum undatum* L. Arctic to New Jersey. 0–650 fath. *Neptunea decemcostata* Say. Nova Scotia to Rhode Island. *Colus gracilis* Da Costa. Maine to Massachusetts.

Carolina would have caused Cape Hatteras to have been below the sea.

It is well known that the Gulf Stream follows the coast close to shore from Florida north to Hatteras. At this point it is deflected from shore and continues northwards a greater distance from land, thereby exerting a lesser influence upon the temperature of the coastal waters north of Hatteras. The submergence of Cape Hatteras in interglacial times might have caused the Gulf Stream to have continued northwards close to shore as far north as New Jersey, probably as far as the Cape Cod region, where it was met, as it is to-day, by the cold Labrador Current.

The presence of the warm waters of the Gulf Stream close to the shores of New Jersey would have caused a climate as genial as that of the Carolinas or perhaps even Florida to-day. That a fairly uniform mild climate existed as far north as Massachusetts is suggested by the presence of the warm water species at Sankaty Head, Nantucket.

However, the fact that during the last interglacial stage the temperature of both air and sea in southwestern Denmark and adjacent regions also was higher than at present (Jessen and Milthers, 1928, pp. 335–6; Nordman, 1928, p. 57) suggests perhaps a more general cause of the high temperature of the water.

VII. The Position of the Shore Line in Cape May Time

Most of the fossil-bearing localities in the Cape May Formation lie close to the present shore line, many of them being on the coastal islands. The fauna of these deposits, if dredging has reached to an appreciable depth, usually indicates marine conditions, that is normal seawater salinity. Those deposits which lie farther back from the coast usually are located near an estuary or river and are made up largely of brackish water forms such as *Venus mercenaria*, *Ostrea virginica*, *Nassa obsoleta*, etc. The localities at Waretown (no. 13), Barnegat (no. 14), Tuckahoe (no. 38) and on Maurice River (nos. 39–44) illustrate estuarine conditions.

It is difficult to determine how far up Delaware Bay the interglacial invasion extended. That more marine conditions existed near the mouth of Maurice River is suggested by the presence of numerous marine forms at Heislerville (locality 39). The shells reported from Raccoon found by the early Swedish settlers (Kalm, 1753) and the marine diatoms in the clays of the Cape May Formation in Philadelphia (Salisbury and Knapp, 1909) suggest that marine or semi-marine conditions may have existed as far up the Delaware as Philadelphia. The finding of a cypress swamp in subway excavations in Philadelphia (Richards, 1932) at about the same depth as a mixture of freshwater and marine diatoms (Woolman, 1890), suggests that Philadelphia may have been near the margin of the marine inroad.

This study does not indicate a very extensive submergence at the time of the deposition of the Cape May Formation in interglacial time if we accept the interpretation given above. The shore line at this time seems to have been only slightly lower than to-day, and the various inroads seem to have been in the vicinity of present day estuaries or rivers.

VIII. Summary

1. Mollusk shells and other remains found during recent years on the coast of New Jersey have in part afforded evidence of a former warmer water fauna and in part of a former colder water fauna.

2. The source of the former has been chiefly sand and fill raised by hydraulic dredges from the back channels down to depths of 55 feet below low water. Many of the species found in these deposits are extinct in New Jersey waters but continue alive in warmer waters farther south. In a few localities the fossils have been found in place.

3. The slight depth of these deposits and the distinctive character of the fossils make it probable that they belong to the Cape May Formation. The warm water character of the fauna is strong evidence in support of Antevs' view that the Cape May Formation was laid down during an interglacial

stage and not at the climax of the last glaciation (Wisconsin) as previously supposed.

4. The cold water fauna is represented by shells, occasionally washed ashore, of species now living farther north. It is suggested that they are derived from a deposit laid down some distance off the present shore line during a glacial stage.

5. The water temperature of New Jersey, when highest, may have equalled that of the vicinity of Cape Hatteras to-day.

6. The cold water fauna suggests a water temperature such as now prevails off northern New England or Labrador.

7. The high water temperature, indicated by the interglacial fauna, may have been caused by a due northward course of the Gulf Stream, brought about by the submergence of Cape Hatteras.

8. The warm water fauna is comparable to the Eem fauna of southwestern Denmark and adjacent regions, also referred to the last interglacial epoch. The Eem fauna suggests a water temperature such as now prevails on the west coast of France or in the Mediterranean.

9. Only a slight submergence at the time of the deposition of the Cape May Formation is indicated. The inroads of the sea seem to have been in the vicinity of present day rivers or estuaries.

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HEIGHTS AND TRAIN-DRIFTS OF LEONID METEORS OF 1932

CHARLES P. OLIVIER

(*Read April 22, 1933*)

As THERE was good reason for thinking that an unusual display of Leonid meteors might be expected during the period from November 14 to 19, 1932, the writer, as President of the American Meteor Society, undertook to organize an elaborate program for their observation. Plans were made for duplicate and triplicate observations in many parts of the United States and Canada and routine observations at numerous other places, as well as in the Southern Hemisphere, where we have active members. Especially ambitious plans were made for the section of the country within a radius of about 150 miles from the Flower Observatory, which is situated just west of Philadelphia. The coöperating parties finally grew to 14 in number, and it is with their results alone that this paper deals.

Some weeks ahead, tentative drafts of plans were sent to several observatories or individuals in this eastern section, all of whom agreed to coöperate. The list of these stations follows:

Station	Observers
1. Flower Observatory, Upper Darby, Pa.	C. P. Olivier D. M. Wills
2. Haverford Township, Pa.	W. P. Wamer R. A. Binckley
3. York, Pa.	S. R. Baker
4. New Brunswick, N. J.	A. Atkinson and 4 assistants
5. New York, N. Y.	J. H. Logan and 2 assistants
6. McDaniel, Md.	J. W. Evans R. H. Wilson
7. Baltimore, Md.	W. R. Small, Jr. P. S. Watson
8. Observatory of J. L. Woods, near Sykesville, Md.	J. B. Field F. C. Oertle

9. Naval Observatory, Washington, D. C.	5 of Naval Observatory staff and 3 assistants
10. Naval Observatory Group at Congressional Country Club, Washington, D. C.	10 of Naval Observatory staff
11. Georgetown College Observatory, Washington, D. C.	Father P. A. McNally, S.J. Father W. J. Miller, S.J.
12. King George, Va.	C. I. Williams
13. Williams Observatory of Hood College, Frederick, Md.	L. B. Allen F. F. Marsh
14. Plainfield, N. J.	R. B. Butler and 2 assistants

Some of the parties joined only at the last moment. This made it more difficult fully to organize the work. All observers were handicapped by a nearly full Moon, which cut out all faint comparison stars and added much to the accidental errors of plotting. Also, no station had ideally clear weather for the whole period; and finally, most of the group were attempting serious meteor plotting for the first time. The personnel included several professional astronomers, several regular amateurs, and a number of persons beginning their observational career.

Most of the parties agreed to observe on the three most promising nights—November 14–15, 15–16, and 16–17—from midnight to 4 A.M., but at the Naval and the Flower Observatories work was to begin at 11 P.M. and run to daylight. Those two stations were also to work an extra night, November 17–18, in case the shower should be a day late. Over half of the planned time was ruined by clouds. It was agreed that all results would be worked up and the heights calculated by the staff of the Flower Observatory. All the records were therefore sent there. The present paper is an attempt to give the computed results in usable and understandable form.

The principal purposes of the observations, in order of increasing importance, were:

1. To obtain an accurate count of all meteors visible in stated simultaneous intervals at different stations.
2. To obtain the heights at which the observed meteors appeared and disappeared.
3. For long-enduring trains left by bright meteors, to study the speed and direction of their drifts.

Briefly, we find that, including all stations, 1861 meteors were observed, including of course many observations of the same object seen from two or more stations. The hourly rates, all very largely corrected for moonlight and haziness, were as follows: November 14–15, 7.5 meteors per hour; November 15–16, 47.3; November 16–17, 20.9; November 17–18, 13.3. Most of the meteors observed were Leonids. We conclude that the maximum occurred on the night of November 15–16, as had been predicted. The actual observed rates were about 0.3 as large as the corrected rates.

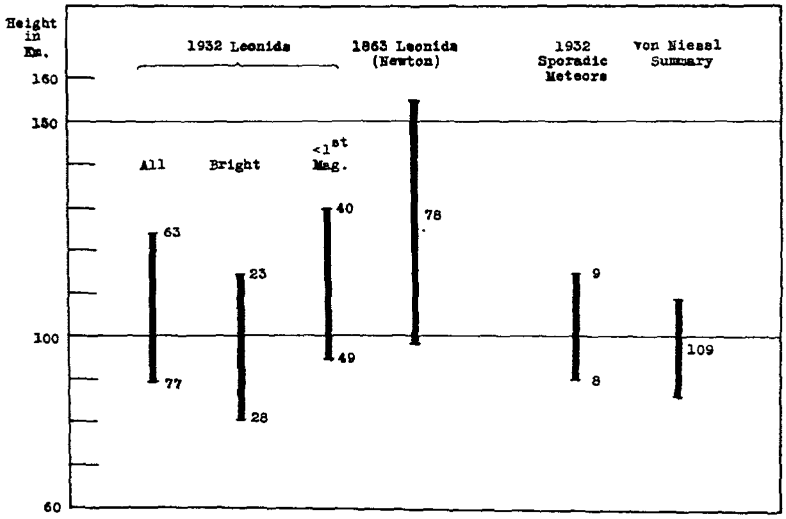
Paths for 928 of the 1861 meteors were plotted upon the maps. Only for meteors which were plotted could heights possibly be derived. A very careful study led to the computation of heights for 94 meteors. Seven of these, for which the error as shown by the interagreement of data for both beginning and end points was over 20 per cent, were omitted as being obviously untrustworthy or not based on observations of the same object. This left 87 meteors (77 of them Leonids) for which some height was determined. Both beginning and end heights were found for 70 of these, beginning height only for 2, and end height only for 15. For these computations 236 individual observations were used, an average of 2.7 stations per meteor.

The average beginning and end points as computed are shown in Fig. 1, and given in tabular form below.

Group	No. of meteors	Beginning height, km.	End height, km.
Leonids, first mag. or brighter	23	114.4	
	28		80.3
Leonids, dimmer than first mag..... .	40	129.7	
	49		94.7
All Leonids.....	63	124.1	
	77		89.5
Sporadic meteors......	9	114.4	
	8		89.6

These facts are shown at once: the Leonids appear at greater heights than sporadic meteors, due of course to their

greater average velocity. Also the height of appearance, 124 km., is somewhat lower than certain published results [Newton, 154.9 km. for beginning and 97.8 km. for end; *Am. Jour. Sci.* (II), 40, 250, 1865]. The almost certain explanation is that, because of the bright moonlight, the 1932 Leonids were not seen, *on the average*, as early in their paths as in the other years; hence the observed beginning points would perforce be



METEOR HEIGHTS
1932 Leonid Epoch and Comparative Data

FIG. 1.

lower. On the contrary, the end points of the paths would be as easy to see in the one case as in the other, and our results agree fairly well with Newton's.

Our results for sporadic meteors agree well with those of von Niessl [109 meteors: 108.5 km., 86.3 km., magnitudes 1 to 5; Smithsonian Misc. Col., Vol. 66, No. 16, 1917]. As we obtained heights for so few sporadic meteors—9 beginning points and 8 end points—this agreement is largely fortuitous.

Two Leonid fireballs, included in the 87 meteors discussed above, left long-enduring trains and therefore furnished the most interesting results. These appeared on the night of

November 15–16, at 14 : 08 and 14 : 35 E.S.T. Fortunately, observations of each were secured from a majority of our stations. Figure 2 shows the path of each in our atmosphere, as projected upon the ground, with respect to the network of stations. Their positions near the center of the network serve to increase the probable reliability of the results.

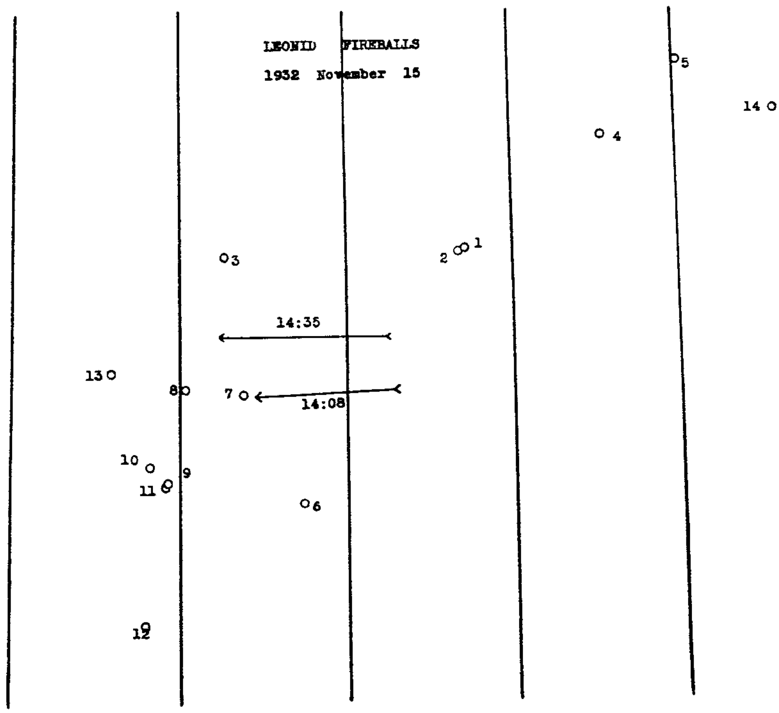


Fig. 2.

Each fireball left a train which, as seen by several of our observers, endured for not less than 4 minutes. By observers at Station 6, who were favored with an exceptionally clear sky, they were seen for about 9 minutes. During this time the trains, being caught by the winds of the upper atmosphere, shifted their positions and changed their shapes. The calculation of this drift and its velocity, although apparently simple

enough in theory, proved to be most complicated in practice. While a large part of the other calculations was turned over to members of our staff, who carried them out with only general supervision, the writer alone is responsible for results on the trains. The problem turned out in fact to be very difficult, and could be solved only by a series of averages and approximations far from entirely satisfactory.

The difficulties were caused both by the accidental errors of the observers, who were much excited by the appearance of these splendid fireballs, and by the impossibility of following *any given point* in the train minute after minute. For instance, is the middle point after 3 minutes the same as the middle point at first? If we assume that it is, and are incorrect, the assumption introduces an error of considerable size. To be more specific, for each train the bright part is a straight line for the first few seconds. Then the train not only shifts laterally, with some changes of shape, but also shortens from each end and (worst of all) unequally. Hence after any given interval, what point corresponds to the original middle point of the straight train?

The data finally deduced for these two Leonid fireballs are as follows:

	I	II
Time of appearance (E.S.T.)	14:08:03	14:35:08
Average estimated magnitude	−3	−4
Began over	$\lambda = 75° 43'$ W. $\varphi = 39° 20'$ N.	$\lambda = 75° 45'$ W. $\varphi = 39° 35'$ N.
Ended over	$\lambda = 76° 33'$ W. $\varphi = 39° 18'$ N.	$\lambda = 76° 45'$ W. $\varphi = 39° 35'$ N.
Beginning height (km.)	119.2 ± 4.5 [1]	141.6 ± 12.0 [3]
End height (km.)	85.8 ± 10.3 [2]	72.8 ± 14.6 [4]
Length of path (km.)	79.3	110.0
Projected length of path (km.)	72.0	85.8
Observed slope of path	24.9°	38.7°
Observed radiant point	$\alpha = 157.5°$ $\delta = +17.7°$	$\alpha = 149.6°$ $\delta = +22.8°$

[1] 3 stations only. The other stations saw not the real beginning point but one some distance lower down.
[2] 8 stations. [3] 5 stations. [4] 10 stations.

Corrections for zenith attraction have not been applied, as they are a small fraction of a degree only.

For the train of fireball I, the height of the adopted central point for 0 minutes was found to be 100.2 ± 5.5 km. As the ends began at once to fade out, heights of upper and lower ends for 0 minutes have little meaning. Basing our calculations on plotted drifts as seen from Stations 6, 7, and 8, we find that for the first four minutes of time after the meteor appeared, the wind was blowing with a velocity of 151 ± 17 km. per hour from N. to a little W. of S. and upward at an angle of 35° with the horizontal. Only at Station 6 could the train be traced for five minutes longer. From a single drawing at Station 6, we could infer that the direction of wind motion did not change, but that the velocity increased perhaps as much as 50 per cent. However, we can state definitely that when this train was visible, from level 100.2 km. to level 105.7 km. there was a wind blowing upward at an angle of 35° in a direction nearly SSW. Stations 10 and 13, while recording long duration for the train, failed to plot the motion. This was due partly to the relative positions of the train and the observers and partly to poorer transparency of the sky at those stations.

For this train the upward component of the wind's motion is derived on the hypothesis that the central point from minute to minute was the same actual part of the train. Were this not true, the direction of motion to SSW. would remain unchanged, but the motion would be more nearly horizontal. The velocity then would be about 20 per cent smaller, *i.e.*, 120 km. per hour. By the third minute the train had already become an elliptical ball of light, about $\frac{1}{2}°$ in diameter, as seen by 2 observers at Station 6. This would correspond to a real diameter of 1.0 km.

For fireball II the phenomena are more complicated. The center of the train was at 87.6 ± 6.1 km. at 0 minutes (based on observations from 5 stations), and at 100.0 ± 8.7 km. at 4 minutes (based on observations from 4 stations), giving a velocity of 236 km. per hour towards the WSW. and upward at an angle of 55° to the horizontal. At this altitude it changed its direction sharply and moved approximately hori-

Meteor Heights

Leonids

No.	Date 1932 Nov.	Time E.S.T. h. m. s.	Ave. est mag.	Beginning height, km.		End height, km.		Numbers of stations
1	14–15	13:47:29	0	62.9	±12.0	53.0	± 3.5	11,13
2		14:15:43	1.5	119.9	27.0	91.9	11.1	5,6,7,10
3		14:18:39	1.2	141.0	8.5	103.3	12.9	2,5,10,13
4		14:33:30	2.5	—		83.9	3.7	5,6
5		15:09:30	1.3	175.5	24.4	135.1	28.4	1,2,8,11
6		15:21:23	2.0	113.7	8.9	90.0	7.6	2,8
7		15:36:46	2.0	179.5	10.5	108.1	8.5	8,10
8		15:43:28	1.0−	125.8	2.2	96.3	0.2	6,13
9		15:51:05	1.3	209.0	5.2	122.3	8.9	7,8,13
10		16:18:05	0.5−	171.2	1.8	157.2	12.9	1,10
11		16:28:46	2.0	126.2	*	84.3	*	1,10
12	15–16	11:35:51	1.5	—		104.4	13.3	1,6
13		12:02:28	2.3	105.2	12.9	89.9	12.2	2,7,8
14		12:22:51	1.5	—		81.9	2.2	2,8
15		12:23:00	1.0	175.8	3.0	74.5	14.4	3,10
16		12:23:01	0.7	—		67.5	5.9	6,7,8
17		12:35:28	2.0	40.4	6.1	24.7	3.9	3,6,8
18		12:35:58	1.0−	138.7	24.2	109.4	16.2	2,7,8,10
19		12:45:03	0.2	130.3	13.7	84.9	4.8	2,7,8,13
20		12:49:52	1.5	121.6	8.1	112.0	9.4	2,8,11
21		12:51:50	2.0	7.4	0.2	4.8	0.6	6,11
22		12:58:27	−0.3	125.5	*	97.8	*	1,6,7,8,11,11
23		13:04:01	2.0	131.5	10.0	112.2	6.1	1,4,8
24		13:06:11	1.5	105.9	6.8	92.8	15.7	7,8
25		13:07:05	0.0	—		90.8	*	2,7,10,11
26		13:12:11	2.0	117.9	1.3	120.3	4.8	2,11
27		13:16:49	0.1	161.8	16.6	114.0	11.8	1,6,7,8,9,11
28		13:21:05	1.0	130.3	18.1	90.2	14.6	8,11
29		13:21:55	1.0	105.2	8.3	95.2	19.7	2,11
30		13:29:59	3.0	52.0	0.4	28.0	5.5	1,4
31		13:34:22	2.0	111.1	6.5	104.2	10.3	7,8
32		13:40:11	1.0	153.5	11.8	140.6	15.5	6,10,11,11
33		13:40:16	1.5	—		160.0	1.7	2,3
34		13:42:48	2.0	102.6	18.4	86.3	0.2	3,13
35		13:45:03	1.5	68.8	1.5	106.1	4.4	6,10
36		13:47:25	0.5	95.9	4.8	84.7	6.6	2,8
37		13:50:27	3.5	118.1	0.6	124.4	1.8	2,8
38		13:51:43	2.0	194.1	3.9	209.6	7.7	8,11
39		13:53:17	0.0	51.1	8.7	45.4	4.6	8,11
40		13:55:06	2.0	109.0	2.4	83.2	0.9	2,11,11
41		13:55:12	1.0	114.8	12.0	98.0	1.3	6,8,8
42		13:56:44	2.0	—		78.6	17.9	1,4
43		14:04:45	1.7	—		55.5	10.1	3,7,8,11
44		14:08:03	−3.0	119.2	4.5	85.8	10.3	1,2,3,6,7,8,10,11, 12

METEOR HEIGHTS—(*Continued*)

No.	Date 1932 Nov.	Time E.S.T. h. m. s.	Ave. est. mag.	Beginning height, km.		End height, km.		Numbers of stations
45	15–16	14:15:04	−2.0	—		36.3	7.0	1,4
46		14:16:35	1.0−	219.6	4.6	115.7	4.2	1,2,8
47		14:17:20	2.0	167.3	7.7	118.8	3.9	7,11
48		14:19:56	−3?	—		61.8	7.7	4,5,11
49		14:23:58	1.0	103.5	17.5	89.7	19.7	6,7,13
50		14:25:45	1.3	—		92.8	5.9	5,6,6
51		14:31:04	1.0	12.5	1.1	8.5	1.1	8,11
52		14:31:53	1.0	132.5	0.9	110.7	0.7	6,7
53		14:35:08	−4.0	141.6	12.0	72.8	14.6	2,3,6,7,8,9,11,12, 13
54		14:52:53	−1.0	56.1	8.7	45.4	1.5	6,8
55		14:53:50	−2.0	109.6	10.1	82.8	5.2	3,9,9
56		14:56:30	0.0	109.4	14.9	111.8	13.8	6,7
57		14:56:54	1.5	113.3	16.6	92.6	26.6	2,6
58		14:58:39	0.5	—		97.0	6.6	1,5
59		15:05:02	1.0	222.9	20.3	89.7	5.4	3,6,7,8,10
60		15:07:34	2.0	270.1	0.0	106.6	11.4	7,11
61		15:13:10	2.0	163.8	16.1	128.0	0.9	8,11
62		15:25:25	3.0	74.2	3.7	73.8	3.9	6,7
63		15:28:05	2.0	78.8	15.1	69.4	11.6	6,8,10
64		15:56:55	1.0	97.8	8.9	74.7	20.1	6,8
65		16:06:53	2.5	—		73.8	0.9	6,10
66		16:09:35	1.0	118.4	1.7	97.8	5.7	6,13
67		16:20:56	2.5	—		86.7	8.7	6,10
68	16–17	13:42:47	2.0	228.6	25.6	162.4	21.2	8,13
69		14:36:19	2.0	130.3	18.6	74.0	12.2	8,9
70		15:01:25	1.5	214.9	19.9	117.2	3.7	8,9,13
71		15:09:06	0.0−	114.4	6.6	45.8	5.2	9,13
72		15:37:30	3.0	64.6	7.2	48.3	2.4	8,9
73		15:45:12	1.5	70.7	1.8	52.0	1.1	8,9
74		15:50:14	2.0	92.2	3.0	52.0	1.8	8,9
75		15:51:15	−1.0	102.2	2.0	48.7	1.7	8,9
76		17:03:23	3.0	111.1	8.9	78.2	1.8	1,9
77		17:06:11	2.0	188.6	10.7	90.8	6.6	1,9

Sporadic Meteors

No.	Date 1932 Nov.	Time E.S.T. h. m. s.	Ave. est. mag.	Beginning height, km.		End height, km.		Numbers of stations
1	14–15	12:59:30	1.7	105.0	7.2	87.6	12.2	2,7,10
2		13:21:05	1.5	98.5	19.0	—		1,6
3		14:13:03	3.0	82.5	0.2	75.1	4.6	1,5
4		14:25:39	1.5	114.0	2.2	94.1	3.7	5,6
5		14:50:50	2.0	104.4	14.4	75.6	15.5	1,7
6	15–16	12:24:56	−1.7	140.8	11.6	129.5	9.4	6,7,10
7		13:42:22	1.0	95.4	4.6	86.0	15.7	8,11
8		15:41:38	1.0	135.6	26.6	82.7	9.2	6,13
9	16–17	13:51:39	1.5	153.1	19.6	—		8,13
10		14:13:53	2.0	—		85.8	6.5	3,8,9

* Graphical solution; no average deviation found.

A dash *after* the magnitude indicates that this meteor was included with dim Leonids because at least one estimate was less than first magnitude.

zontally as seen from Station 6 for 5 + minutes, still to the left (*i.e.* due W?) and with about the same angular velocity. This observed motion would mean a *minimum* linear velocity at this altitude (100 km.) equal to that possessed at the lower level.

This train was the brighter of the two, and at the end of 4 minutes was an elliptical mass $3^\circ \times 1^\circ$ as seen from Station 6. This corresponds to a real size of 3.8 km. × 1.3 km. No possible combination of the data allows us to eliminate the strong upward component, as might possibly be done for the first fireball.

For this second fireball's train, Mr. J. L. Woods at Station 8, actually his private observatory near Sykesville, Md., secured a remarkable photograph with an anastigmat lens, speed f 4.5, focal length $15\frac{3}{4}$ inches, and Eastman 40 plate. It was taken beginning 5 seconds after the fireball had ap-

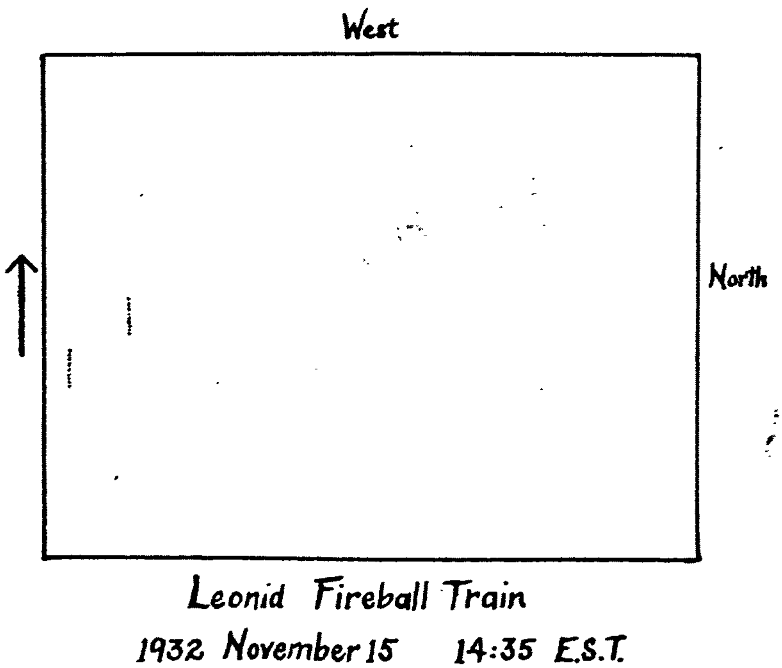


FIG. 3.

peared, with 9 exposures of 10 seconds each, with intervals of 10 seconds between them. This unique photograph is therefore a composite one. Figure 3 is a drawing from the original, which was too faint for satisfactory photographic reproduction. Comparing the photographic position with the path computed on the basis of all of the visual observations, for Station 8 the adopted path is 3° too near the zenith, the adopted zenith distance being 28° instead of 31°. If this 3° were to be taken as an absolute correction, it would mean that the heights for the train are all about 12 per cent too great. However, as the heights were independently derived on data from 10 stations, and as it is by no means certain that this is an *absolute* correction, it did not seem practicable to apply it. In any case, 12 per cent is of the order of the probable error.

The photograph is particularly interesting in that it shows how all the elements of the train tended to move in definite directions and to form the eventual central ball of light. Of course, all of the detail seen on the original negative cannot be reproduced in the drawing.

Another meteor train was seen on the same night, November 15–16. It was observed at 13 : 07 : 05 E.S.T. by P. S. Watson, and was plotted from Station 7 only. It lasted for 30 seconds and showed a distinct drift to the S., the train itself being almost E. as seen from Station 7.

As illustrative of train motions, the writer adds sketches (Fig. 4) of a Leonid train seen by him, and carefully drawn at the time, on November 16–17, 1931, at 16 : 01 E.S.T., while observing in the clear air of the Catskill Mountains. This train lasted in all 7 minutes as seen with the naked eye, 10 minutes with an opera glass. It illustrated beautifully the fact that the winds in different strata of the upper atmosphere have both different velocities and different directions. The center of the train had at 0 minutes an altitude of about 30°; at the end of 7 minutes it had drifted vertically downward about 7°, in general staying parallel to itself. It was in the SW., so whatever angle the drift actually made with the horizon, it was certainly moving toward the SW.

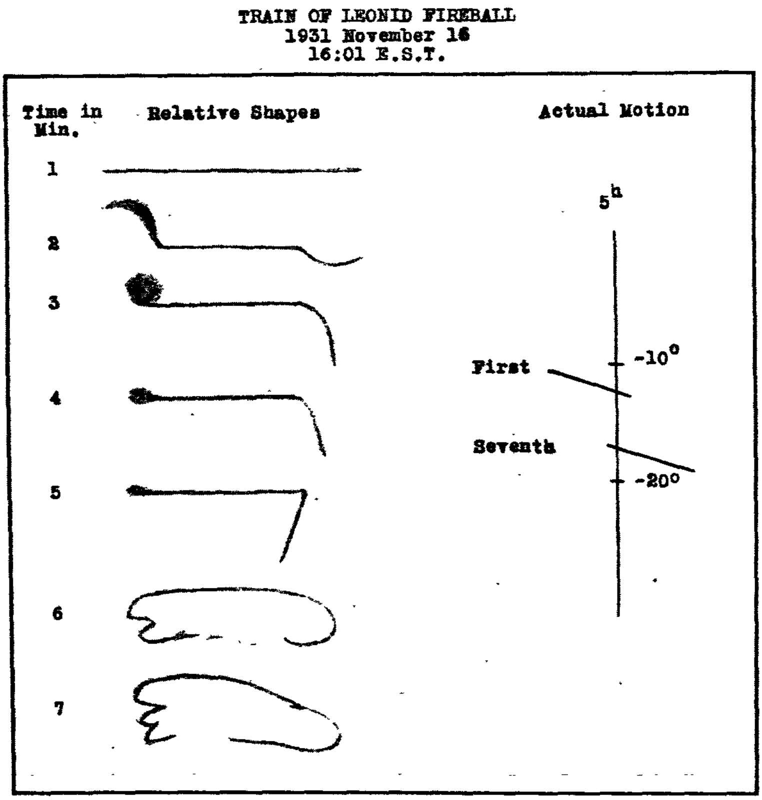


FIG. 4.

From our 1932 Leonid campaign, we have been able to deduce the directions and velocities of the drift of two Leonid fireball trains, and, perhaps most important of all, to show that there are *rising* currents in the upper atmosphere. As only by long-enduring meteor train drifts are we as yet able to study these upper atmospheric strata, it hardly need be emphasized that no reasonable efforts should be spared for future determinations of train motions.

The writer desires to express to the directors of the co-operating observatories and to all individuals who took part in

the observations his most sincere thanks for their enthusiastic coöperation. The results obtained are common property; they could not have been obtained from any one station, and every person who helped deserves his full share of credit. The members of the Flower Observatory staff have assisted in both observation and computation, but special mention should be made of Mrs. Doris M. Wills, who computed most of the heights, made the drawings, and assisted the writer in the general working up of the data.

LOUREIRO AND HIS BOTANICAL WORK

E. D. MERRILL

(*Read April 20, 1933*)

THE establishment of the simple binomial system for designating different species of plants and animals by Linnaeus in 1753 acted as a tremendous stimulant to descriptive biology, resulting in the publication of numerous fundamental works in the latter half of the eighteenth century. Many of these were frankly based on the works of Linnaeus, but modifications and improvements were soon initiated. This was, moreover, owing to the wealth of new material being brought back by travelers and explorers, a period when the European outlook on the biological sciences was rapidly expanding. While most of the technical work was done in Europe, soon a school of local investigators developed outside of that continent, and one of its pioneers was João de Loureiro, S. J.

Loureiro was born in Lisbon, Portugal, in 1710. Soon after his admission to the Jesuit Order he was sent to the Orient, first spending three years in Goa, followed by four years at Macao. From the latter place he was sent to Cochinchina on a special mission in 1742. Finding that missionary activities were not in favor, he entered the service of the King of Cochinchina as mathematician and naturalist, and here he remained for the next thirty-five years. He became interested in botany through the necessity of developing his knowledge of the properties and uses of local medicinal plants. In December, 1777, Loureiro proceeded to Canton, leaving China on his return to Lisbon in March, 1781. He died in Lisbon in October, 1791.

His basic botanical work the *Flora Cochinchinensis*,[1] a

[1] **Loureiro, J.** Flora Cochinchinensis: sistens plantas in regno Cochinchina nascentes, quibus accedunt aliæ observatæ in Sinensi Imperio, Africa Orientali,

volume of 744 pages, in which are described 672 genera and 1292 species, appeared in 1790; of these 185 genera and about 630 species were described as new. This was in all respects a remarkable accomplishment, for Loureiro had no formal botanical training, he had almost no botanical books, and until well toward the end of his career he had had no contacts with other botanists, and such contacts as he did later develop were through correspondence. It is scarcely to be wondered at that Gomes [1] in his eulogy of Loureiro published in 1868 should repeat Schreber's exclamation: "Mirandum est sane virum omnibus libris destitutum tam erudite de plantis potuisse judicare." While the value of this work has been generally recognized, yet its publication set up a number of problems the solution of many of which proved to later investigators to be almost insuperable, and even after my own intensive and critical study of all data bearing on the subject extending over a period of about 14 years, there still remains a small residue of doubtful species which will in all probability not be much further reduced.

All biologists realize that the same species has very frequently been described many times under different technical names. One of the greatest difficulties that faces modern taxonomists is the problem of accounting for all binomials within a group being monographically studied, and of correlating the various published descriptions, short and long, good, bad, and indifferent, of various authors. For a variety of reasons it has hitherto been impossible definitely to place a high percentage of the species described by Loureiro, and hence impossible to correlate much of his work with that of his contemporaries and successors; in fact many of his successors have apparently ignored Loureiro's contributions because

Indiasque locis variis, omnes dispositæ secundum systema sexuale Linneanum. I–XX, 1–744. 1790, ed. 2, I–XXIV, 1–882. 1793.

The second edition is a republication of the first one with no important changes, the editor, C. L. Willdenow, occasionally adding suggested reductions in the form of footnotes.

[1] **Gomes, B. A.** Elogio historico do Padre João de Loureiro lido na sessao da Academia Real das Sciencies de Lisboa em 30 de Abril de 1865. Mem. Acad. Sci. Lisb. Cl. Pol. Mor. Bel.-Let., n.s., 4(1): 1–31. 1868.

of the complexity of the problem. Had he consistently prepared herbarium specimens representing the forms on which his descriptions were based, and had all such material been preserved, the individual problems could be solved by the simple expedient of re-examining types; but unfortunately Loureiro did not consistently prepare such specimens, and some of those he did prepare have been destroyed. Loureiro's numerous unplaced binomials, and a high percentage of those proposed by his successors, but based on his descriptions, bulk large in all lists of excluded and doubtful species. In view of the relatively early date of his publication, 1790; in view of the fact that some modern botanists working on the floras of the regions to which the *Flora Cochinchinensis* applies have to a certain degree ignored his work; and in the interest of stability of nomenclature, it has appeared to me essential that an intensive study of Loureiro's descriptions be made in correlation with what has been published by numerous authors relating to the problem and to the areas concerned.

Undoubtedly most if not all authors who must concern themselves with the identity of Loureiro's species will heartily agree with A. de Candolle[1] who, in discussing enigmatic descriptions of various authors including those of Fathers Velloso, Blanco, and Loureiro, states: "Il est à regretter que ces révérends ecclésiastiques, et même le Père Plumier, leur predécesseur, ne se soient pas contentés d'écrire des homélies. Bonnes on les aurait lues, mauvaises on les aurait mises de côté; tandis qu'en histoire naturelle l'existence de certains noms et certaines planches rend nécessaire de consulter indéfiniment les plus mauvais ouvrages." Yet the descriptions exist and the Loureiroian names must be or should be accounted for, as well as more than 750 binomials proposed by Loureiro's successors but based on his descriptions; this in spite of the fact that in the published parts of Lecomte's modern *Flore générale de l'Indo-Chine*, which covers the area to which the *Flora Cochinchinensis* principally appertains, I have detected in excess of 320 binomials proposed by Loure-

[1] **Candolle, A. de** La Phytographie, 141. 1880.

iro or based on Loureiro's descriptions, which are not mentioned in that work, yet which refer strictly to the flora of Indo-China.

It seems to me that as we have an International Code of Botanical Nomenclature, and that as this code, with certain generic exceptions, recognizes the principle of priority, those botanists who accept this code, and this includes the vast majority of systematists, should follow its regulations with reasonable consistency. In the interest of stability in nomenclature it is hence desirable that as many as possible of the earlier descriptions be definitely placed in order to avoid the interminable changes that must be made under generally accepted rules. Why should a species described, let us say, in 1930 be recognized as valid when the same species was described, under another name, as early as 1790, and the earlier name is still valid? In the course of this work I have noted no less than 16 "new" species described since 1900 that Loureiro clearly and accurately described 110 to 140 years earlier, under names that are still valid, and in some cases the actual Loureiroian type specimens are still extant. If we recognize the species of such outstanding systematists as Linneaus, de Candolle, or Bentham, and those of contemporary authors, why should we not accept those of Loureiro where his descriptions are sufficiently exact clearly to indicate just what he was attempting to describe, even if he did very frequently place his new species in the wrong genus, and even in the wrong Linnæan class and order?

Perhaps the chief reason for some apparent discrimination against Loureiro is the fact that so many of his species were originally ascribed to genera to which they cannot possibly belong. Later monographers treating these genera, but not familiar with the families and genera to which these numerous misplaced species belong, were naturally unable to place them, and so the names cumber botanical literature as excluded, enigmatic, and unplaced ones.

Many of Loureiro's descriptions are models of form, concise and accurate, and well balanced in all respects; in fact

many are definitely superior to those of some of his contemporaries and successors. Others are most unsatisfactory, generalized, incomplete, sometimes inaccurate or even erroneous. Some are apparently based on mixtures of material. Others are based on actual plants with some characters added from pre-Linnæan illustrations cited, the illustrations often representing some totally different genus and species. In many cases where he erroneously placed species in Linnæan genera and described his species from flowering specimens, he added a generalized fruit description apparently to make his species description conform to the generic characters as given by Linnæus; in some such cases, as can be proved by an examination of extant types, the species characterized by Loureiro not only does not belong in the Linnæan genus to which it was assigned, but not even in the same family of plants.

In other cases he placed within the same genus plants that are totally unallied to one another, a typical example being *Juglans* with three species, one a true *Juglans*, one an *Aleurites* of the Euphorbiaceæ, and one a *Terminalia* of the Combretaceæ. One would certainly not expect to find a species of *Hydrangea* described as a *Primula;* a cucurbitaceous plant as an *Euonymus* of the Celastraceæ, an araliaceous plant as a *Plectronia* of the Rubiaceæ; a simarubaceous plant as a *Crassula;* a meliaceous one as a *Santalum;* an *Hypericum* as a *Reseda;* a grass as a species of *Juncus;* and a *Juncus* as a species of *Scirpus;* a rutaceous plant as a *Toluifera;* a myrtaceous one as a *Cedrela;* a moraceous plant as *Salvadora*, and numerous similar cases, yet these are only a very few of numerous similar cases in Loureiro's work.

In about 40 instances in his use of the Linnæan generic names nothing so placed by him represents the Linnæan generic concept, and many do not even represent genera within the family to which the Linnæan genus belongs. Many of the genera described by Loureiro as new do not properly belong in the Linnæan classes and orders in which he placed them. It is scarcely to be wondered at that many

of his really good species descriptions have remained unplaced because no botanist could be accused of lack of diligence if he failed to detect the fact, were he monographing, for example, the Meliaceæ, that Loureiro's description of *Santalum album*, which should be a Santalaceous plant, actually appertained to the meliaceous *Dysoxylum loureiri* Pierre.

No less than 54 new generic names and somewhat more than 750 new binomials typified by Loureiro's descriptions have been proposed by various authors in the past 140 years. These proposed changes were in part due to changed concepts of generic limits, in part due to the fact that in scanning Loureiro's descriptions it was noted that the characters assigned by him under various Linnæan binomials did not conform to the characters of the Linnæan species; hence in numerous cases new names were prepared without any true concept of what Loureiro was attempting to describe. Some changes in name, on the other hand, were purely arbitrary. While in some cases individuals have actually examined extant Loureiro types, more often the work has been purely bibliographic. Most investigators did not have access to the relatively few Loureiro types or to much material secured by later collectors from the classical localities whence Loureiro's actual specimens came, and some failed to realize how essential it was to examine such material in connection with a critical study of Loureiro's descriptions.

The value of extensive collections from classical localities was impressed upon me in connection with the similar problem of the elucidation of the 1136 species and varieties described by Blanco [1] in his *Flora de Filipinas*.

Here was a case of an author of numerous new binomials who preserved no botanical specimens. Blanco's species, up to the beginning of the present century, were even more enigmatic to European taxonomists than were those of Loureiro, yet through a critical study of all of his descriptions

[1] **Blanco, M.** Flora de Filipinas segun el systema sexual de Linneo I–LXXVIII, 1–887. 1837, ed. 2, I–LIX, 1–619. 1845, ed. 3, **1**: I–XXX, 1–350, I–VI, 1877, **2**: 1–419. I–VIII, 1878–79, **3**: 1–271. I–VI, 1879, **4**(1): I–XVII, 1–108. 1880, **4**(2): I–VI, 1–63. 1880, **4**(3): I–IX, 1–375. *Pl. 1–473*. 1880–83.

in conjunction with very extensive modern collections of herbarium material, nearly all of the Blancoan problems were solved, and most of his descriptions correlated with those of other authors. This involved the acquisition of a wide working knowledge of the entire Philippine flora, and particularly a familiarity with the floras of those regions whence Blanco secured the material on which his descriptions were based. Detailed attention had to be given to the local names cited by him, the habitats, economic uses, localities, and time of flowering. Toward the end of the study, which was completed and published in 1918,[1] special trips at particular seasons to specific localities were involved in order to secure material that with certainty represented some particular Blancoan species. A somewhat similar consideration of the pre-Linnæan species described by Rumphius [2] in his *Herbarium Amboinense* was issued in 1917.[1] Less extensive papers were also prepared on the more or less enigmatic species of Osbeck [2] and Burman.[3]

There remained, however, the very important *Flora Cochinchinensis* of Loureiro, a publication that presented numerous special problems peculiarly its own. In 1919 an extensive manuscript consisting of xxxvi + 693 typescript pages was prepared on Loureiro's species, but publication was deferred pending the acquisition of actual collections of botanical material from the classical localities, particularly in the vicinity of Canton, China, and Hue, Indo-China, and an opportunity to secure corroborative data from extant Loureiroian types in the Museum d'histoire naturelle, Paris, and the British Museum, Natural History, London. During 1931–32

[1] **Merrill, E. D.** Species Blancoanæ. A critical revision of the Philippine species of plants described by Blanco and by Llanos. *Bur. Sci. Publ.*, **12**: 1–423, map, 1918.

[2] **Rumphius, G. E.** Herbarium Amboinense. **1**: 1–300, *pl. 1–32*, 1741, **2**: 1–270, *pl. 1–87*, 1741, **3**: 1–218. *pl. 1–141*. 1743, **4**: 1–54, *pl. 1–82*, 1743, **5**: 1–492, *pl. 1–184*, 1747, **6**: 1–256, *pl. 1–90*, 1750, **7**: (Auctuarium) 1–74, *pl. 1–29*, 1755.

[1] **Merrill, E. D.** An Interpretation of Rumphius' Herbarium Amboinense. *Bur. Sci. Publ.*, **9**: 1–595, map, 1917.

[1] **Merrill, E. D.** Osbeck's Dagbok ofwer en Ostindsk Resa. *Am. Journ. Bot.*, **3**: 571–588. 1916.

[1] **Merrill, E. D.** A review of the new species of plants described by N. L. Burman in his *Flora Indica*. *Philip. Journ. Sci.*, **19**: 329–388. 1921.

active work was again commenced on this project and the entire manuscript was critically rewritten.

With Loureiro, as with Blanco and with Rumphius, it was first necessary to familiarize myself with the extent, characters, and peculiarities of his descriptions, with the regions covered and the extant publications appertaining to those regions, with the history and present disposition of such herbarium material as he did preserve, and with the disposition made of Loureiro's species by subsequent authors from 1790 to date. The problem was more complex than that of Blanco, because Blanco dealt only with Philippine species, and these mostly from rather restricted areas, while Loureiro's work covered a much wider field, as evidenced by the fact that of the 1292 species he actually described, about 697 came from Indo-China, 254 from China, 292 from both China and Indo-China, 29 from tropical East Africa, 9 from Mozambique, 8 from Zanzibar, 5 from India, 2 from the Malay Peninsula, and 1 each from Sumatra, the Philippines, and Madagascar.

After assembling fairly comprehensive collections from the two more important classical localities, the general vicinity of Canton, China, and Hue, Indo-China, and identifying this material in accordance with modern nomenclature, it became necessary then again to identify these specimens in terms of Loureiro's nomenclature. This was no simple or easy task because of the nature of Loureiro's descriptive data. In many cases the identity of the species that Loureiro described was obvious; in others the problem was distinctly complicated, and in many cases, after exhausing all clues in the descriptions, local names cited, economic uses indicated, habitats, and other data, the only recourse left was to apply the process of elimination. In simple terms this meant studying the description of the unplaced species until such distinctive characters as were mentioned were well fixed in one's mind, and then scanning lists and descriptions of all genera and species known to occur in the region indicated regardless of their family affiliations until one was found that conformed in essentials to the data given by Loureiro.

Through these methods, supplemented by an actual examination of some of Loureiro's types, and photographs of others, it became possible to place all but one of Loureiro's 185 new genera, 14 of which were unplaced at the beginning of this study, and to identify all but 3 of the 54 genera proposed by other authors but based on species described by Loureiro. At the same time a considerable number of Loureiroian species were definitely placed which no previous author had been able to dispose of in a satisfactory manner.

The general results obtained to date are as follows. Of the 185 genera described by Loureiro as new, 44 are valid under all rules and but one remains unplaced; of the 54 new generic names proposed by Loureiro's successors but based wholly on his descriptions, 3 remain unplaced because of our inability to indentify the Loureiroian species on which the new generic name was based. Of the 659 binomials accredited to Linnæus, on Loureiro's assumption that he was describing the same species that Linnæus intended, he was in error in 360 cases, his percentage of error in the interpretation of Linnæan species being 54 per cent as compared with Blanco's percentage of error of 60 per cent in his Philippine work. Of the 630 species that Loureiro actually described as new, only about 25 remain absolutely unplaced, while from the data at present available, about 60 others can with certainty be referred only to the genera to which they apparently belong. In the course of this study, in addition to placing definitely most of Loureiro's binomials in relation to those proposed by other authors, more than 750 based wholly on Loureiro's descriptions by other authors have automatically been placed as the status of the Loureiroian species were determined.

In view of the fact that Loureiro's work was published in 1790, only 37 years after the binomial system was proposed; that he described as new no less than 185 new genera and 630 new species, many of which, in both categories, were unplaced until within the past few years, the changes in nomenclature resulting from this study are remarkably few. Were strict

priority followed in the acceptance of generic names, about 25 currently used ones would automatically be replaced by those of Loureiro, but fortunately for the stability of nomenclature most of these changes are rendered unnecessary by the list of *nomina generica conservanda* approved by the International Botanical Congresses at Vienna (1905), Brussels (1910), and Cambridge (1930). In but 2 cases am I suggesting the acceptance of Loureiro's generic names, and these only in the cases of small and economically or horticulturally unimportant genera—*Picria* Lour. (1790) for *Curanga* Juss. (1807), and *Rotula* Lour. (1790) for *Rhabdia* Mart. (1827). *Desmos* Lour. is accepted as the proper designation for the so-called Old World species of *Unona*, as *Unona* proper is strictly an American group. For those who insist on strict priority and ignore the list of conserved generic names the necessary changes would be much more far-reacing, as indicated by the following list. The Loureiroian generic names in the first column are all older than the currently used ones in the second column.

Aulacia	*Micromelum* Blume, 1825.
Baryxylum	*Peltophorum* Walpers, 1842.
Bembix	*Ancistrocladus* Wallich, 1829.
Botria	*Ampelocissus* Planchon, 1887.
Callista *Ceraia*	*Dendrobium* Swartz, 1790, 1800.
Columella *Lagenula*	*Cayratia* A. Jussieu, 1823.
Cylindria	*Linociera* Swartz, 1791.
Dasus	*Lasianthus* Jack, 1823.
Diceros	*Limnophila* R. Brown, 1810.
Diphaca	*Ormocarpum* Beauvois, 1806.
Eystathes	*Xanthophyllum* Roxburgh, 1814, 1819.
Grona	*Desmodium* Desvaux, 1813.
Melodorum	*Mitrephora* Hooker f. & Thomson, 1855.
Nephroia	*Cocculus* de Candolle, 1818.
Pedicellia	*Mischocarpus* Blume, 1825.
Phyllaurea	*Codiæum* A. Jussieu 1824

Phyllodes	*Phrynium* Willdenow, 1797.
Picria	*Curanga* A. Jussieu, 1807.
Placus	*Blumea* de Candolle, 1833.
Polychroa	*Pellionia* Gaudichaud, 1826.
Pselium	*Pericampylus* Miers, 1851.
Rhaphis	*Chrysopogon* Trinius, 1820.
Rotula	*Rhabdia* Martius, 1827.
Sarcodum	*Clianthus* Banks & Solander, 1832.
Tralliana	*Colubrina* L. C. Richard, 1827.
Triceros	*Turpinia* Ventenat, 1803.
Vanieria	*Cudrania* Trécul, 1847.

Strict priority would not mean the acceptance of all of these Loureiroian generic names for in some cases there are generic names still older than those of Loureiro that have been rejected in favor of the names appearing in the second column. Thus *Mayepea* Aublet (1775) is older than *Linociera* Swartz and *Cylindria* Loureiro, *Meibomia* Adanson (1765) is older than *Desmodium* Desvaux and *Grona* Loureiro, *Cebatha* Forskål (1775) is older than *Cocculus* de Candolle and *Nephroia* Loureiro, and *Ambulia* Lamarck (1783) is older than *Limnophila* R. Brown and *Diceros* Loureiro.

AN UNUSUAL CHIMÆRA

WILLIAM TRELEASE

(Read April 20, 1933)

THE appearance of different morphological types in parts of one and the same individual, when it is differentiated from simple bud-variation [1] or vegetative mutation, has given rise to the use of the word Chimæra as applied to plants. Some variegated plants, when their green and aberrantly colored parts become segregated, furnish the most commonly seen examples,[2] but those which are most striking and obvious are afforded by dissimilar forms which have been united by grafting or budding and subsequently appear segregated in various parts of the resultant plant. It is cases of this kind which have given rise to the expression "graft-hybrids" [3]—a notable example being the long-known *Laburnocytisus* (or *Cytisus*) *Adamii*,[4] the origin of which is unrecorded. It produces some flower clusters that would pass for the familiar Laburnum or "Gold Regen" and others that would be taken unhesitatingly for *Cytisus purpureus*, if they had not come from the same plant, or an occasional flower of the other sort appears in a cluster of one of these types, while elsewhere the individual is more or less intermediate between the two extremes. This general intermediate character suggests that it is really a hybrid between the two which segregate here and there on its representatives, and the similarity between its behavior and that of other Chimæra-producing forms that are of known graft origin, leads to the supposition that it is of like origin.

So far as I know, no hybrids coming from the fertilization of one species by another have been shown to segregate here and there on one individual in the Chimæra fashion—though not all plants showing the general phenomenon are necessarily pure-bred.

The case here presented comes very close to furnishing an

example of the appearance of Chimæras in a scarcely questionable though presumptive seed-hybrid.

Several years ago, Mr. Orpheus M. Schantz, an observant nature-lover, noticed a bur oak with more silvery and more deeply cut foliage than usual, at Willow Springs, Illinois, and this year made a series of photographs of the tree and collected specimen leafy and fruiting twigs from it. There is no reason to doubt that the tree—which an ordinary observer would pass by as a bur oak—is really one of the comparatively few known examples of the hybrid between that species and the white oak which has been named × Quercus Bebbiiana in commemoration of an Illinois tree-lover of an earlier generation, who first found it; but in foliage, buds, and fruit, this new one differs strikingly from them, and its discoverer is publishing elsewhere an account of it under the name × Q. Bebbiiana Orpheusi Pepoon & Trel.

If this were the whole story, there would be no need for this supplementary communication; but there is more to be said about the tree, as a comparison of the accompanying plates shows at a glance. They represent, in natural size, two of the branchlets brought in by Mr. Schantz.

One of them (plate I) might easily pass for the bur oak (*Quercus macrocarpa*) in an occasional small-fruited form, except for its whitened leaves and more rounded buds, and the short acorn presents the familiar dull downiness of a bur oak acorn.

The other (plate II) has the glossy elongated acorns and shallow cups of the white oak, but with the cups somewhat fringed as they never are in a pure white oak.

As oaks grow, there can be little question that this tree originated from an ovule of white oak fertilized by bur oak, or of bur oak fertilized by white oak. There is nothing unusual in the occurrence of a new and different example of such a natural cross. What is unusual is the dimorphism in its fruit, and still more unusual is the segregation of the two kinds of fruit, rendering the tree a veritable and striking Chimæra, and opening up along a new line the nature and

mechanism of the aberration from nominal morphology that this word stands for.

Some References

Apart from the general subject of bud-variation—illustrated strikingly in many forms of fruit and particularly in the nectarines or glabrous-fruited peaches of several types, on which Darwin collected such extensive data, the outstanding publications on the subject here immediately under discussion, which have been assembled for me by my colleague Professor C. F. Hottes, are here grouped with particular reference to some of the foregoing statements on which they bear most closely.

1. Bud Variation

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Emerson, R. A., "The Nature of Bud variations as Indicated by their Mode of Inheritance." *Amer. Nat.*, **56**: 64. 1922.

2. Variegated Chimæras

Baur, E., "Das Wesen und die Erblichkeitsverhaltnisse der Varietates albomarginatae hort. von Pelargonium zonale." *Zeitschr. f. ind. abst. u. Vererbungslehre*, **1**: 330. 1909.

——. "Pfropfbastarde, Periclinalchimären und Hyperchimären." *Ber. deutsch. Bot. Ges.*, **27**: 603. 1909.

——. "Pfropfbastarde." *Biolog. Zentralblatt*, **30**: 497. 1910.

Noack, Konrad L., "Entwicklungsmechanische Studien an panaschierten Pelargonien." Zugleich ein Beitrag zur Theorie der Periklinalchimaren. 56 Text figuren. *Jahrb. f. wiss. Bot.*, **61**: 459. 1922.

3. Graft Hybrids and Chimæras

Edler, W., "Ein Beitrag zur Frage des Vorkommens von Pfropfmischlingen." *Fuhlings Landw. Zeitschr.*, **57**: 170. 1892.

Winkler, H., "Ueber Pfropfbastarde und pflanzliche Chimären." *Ber. deutsch. Bot. Ges.*, **25**: 568. 1907.

——. "Solanum tubingense, ein echter Pfropfbastarde zwischen Tomate und Nachtschatten." *Ber. deutsch. Bot. Ges.*, **26a**: 595. 1908.

——. "Weitere Mitteilungen über Pfropfbastarde." *Zeitschr. f. Botanik.*, **1**: 315. 1909.

——. "Über das Wesen der Pfropfbastarde (Vorl. Mitteilung)." *Ber. deutsch. Bot. Ges.*, **28**: 116. 1910.

——. "Über die Nachkommenschaft der Solanum-Pfropfbastarde und die Chromosomen-zahlen ihrer Keimzellen." *Zeitschr. f. Botanik*, **2**: 1–38. 1910.

——. "Unters. ueber Pfropfbastarde." Jena. 1912.

Strasburger, E., "Über die Individualitat der Chromosomen und die Pfropfhybriden-Frage." *Jahrb. f. wiss. Bot.*, **44**: 482. 1907.

——. "Meine Stellungnahme zur Frage der Pfropfbastarde." *Ber. deutsch. Bot. Ges.*, **27**: 511. 1909.
Blakeslee, A. F. and J. Belling, "Chromosomal Chimæras in the Jimson Weed." *Science*, n.s., **60**: 19. 1926.
Meyer, Joh., "Die Crataegomespili von Bronvaux." *Zeitschr. f. ind. Abst.- u. Vererblehre*, **13**: 193. 1915.

4. Laburnocytisus

Beijerinck, M. W., "Über die Entstehung von Cytisus purpureus aus Cytisus Adami." *Ber. deutsch. Bot. Ges.*, **26a**: 137. 1908.
Buder, J., "Studien an Laburnum Adami. I." *Ber. deutsch. Bot. Ges.*, **28**: 188. 1910.
——. "Studien an Laburnum Adami. II." *Zeitschr. f. ind. Abst.- u. Vererblehre*, **5**: 209. 1911.

PLATE I

TRELEASE—CHIMÆRA OAK HYBRID

PLATE II

TRELEASE—CHIMERA OAK HYBRID

ORTHOGENESIS AND THE POWER AND INFIRMITIES OF MAN

GEORGE W. CRILE

(*Read April 21, 1933*)

THERE is a group of diseases which occur almost exclusively in civilized man, the origin and nature of which, though they have been long and intensively studied, are not clearly understood. Among such diseases are hyperthyroidism, neurocirculatory asthenia, peptic ulcer, and allied diseases.

These diseases obviously do not appear in plants; they do not appear in protozoans, nor in mollusks, nor in reptiles. They do not appear either in wild animals or in domesticated mammals. They are exceedingly rare in primitive man, and they are uncommon in the lower ranks of civilized man. These diseases trail man's ascent and the more highly civilized man becomes the more prevalent do these diseases become. They have stalked man in his rise, and are as an evil shadow that has risen with him.

We should first exclude from our consideration those factors in our civilization that are not the primary cause of these diseases, such as infections, diet, climate, and excessive physical work.

Infections.—These diseases peculiar to civilized man could not be primarily due to infections for the same infections affect all races of man in all walks of life, and these diseases affect the lower animals as well. There is not a single fact that suggests that a specific infection causes any of these diseases in the sense that tuberculosis, typhoid, etc., are caused by specific infection. Infections play a rôle in these diseases but that rôle is clearly secondary.

Diet.—It is even more clear that diet is not a primary factor in the causation of these human diseases for they appear independently of diet. No diet is known which can, *per se*,

prevent or cure any of these diseases, although diet does play a secondary rôle.

Climate.—These diseases can not be due to altitude, to humidity, or to temperature, as they appear wherever civilized man appears.

Excessive Physical Work.—If physical overwork were the prime factor in the causation of these diseases, then the horse should have peptic ulcer, or hyperthyroidism, or neurocirculatory asthenia, as the horse works as consistently as man and becomes as physically tired as man, and the protoplasm of the horse obeys the same chemical and physical laws as does the protoplasm of man, but the horse does not have these diseases. Moreover, the laborer is not on the whole so susceptible to these diseases as is the intellectual and emotional worker. Therefore, these diseases are not due primarily to excessive muscular work.

If these diseases are not due to infection, to climate, to food, or to muscular work, if the specific cause of these diseases is not found in our immediate physical environment, we must seek for the cause in our human relationships, the background of which is our phylogeny. The predisposing causes of these diseases must be found in the past; they must be found in factors in our phylogeny, not in our ontogeny—in the long yesterday, not in today. It is to our racial history that we must turn in order to discover the background of these diseases so peculiar to civilized man.

Paleontologic Record

From studies of the fossil record, the principle of orthogenesis which has been elaborated by von Nägeli and Eimer was formulated.[1]

Orthogenesis means straight (ortho) creation or production (genesis). This principle as explained by Eimer means that when a species begins to vary definitely in any direction, the species continues to vary in that direction. There is nothing

[1] Newman, H. H., *Evolution, Genetics and Eugenics.* 2d Ed., Chicago, 1925. Cited by Lull, R. S., *Organic Evolution.* New York, 1929, p. 152.

inherent in protoplasm which can change such a tendency; even if it is going wrong, this tendency can not reverse itself.

For millions of years, even through geologic ages, such a continuing variation in one direction may serve the species well, but finally the species may become so handicapped by the unfavorable physical result of the variation that the species can no longer survive.

According to Lull the sauropod dinosaurs are examples of such extinction resulting from an extreme application of the principle of constancy of variation in the direction of size. The race of the dinosaurs became extinct because of gigantism and gigantism resulted from the application of the law of orthogenesis.

The principle of orthogenesis, however, applies not only to changes in the entire organism as in the case of the dinosaur but it applies also to a structure or an organ of the individual of a species. Thus the growth of excrescences as of the horned and armored dinosaurs led to the extinction of the race.[1] The most conspicuous and best known example of such an application of the law of orthogenesis in the over-specialization of a structure of an animal far beyond the limits of usefulness is seen in the case of the Irish elk.[2] In this species the antlers by which this animal was once aided in achieving survival increased continuously until the weight of the antlers bore his race down to extinction.

The handicapping and final extinction of a species by the application of the principle of orthogenesis might fittingly be called *pathologic phylogeny*, just as injurious changes in the structure of the organs and parts of animals are designated as *pathologic anatomy* and injurious changes in function are designated *pathologic physiology*. Pathologic anatomy and pathologic physiology refer to the individual not to the species. But if the damaging change in anatomy or physiology is present in successive individuals over long periods of time, a pathologic phylogeny is established.

It is our purpose in this paper to examine certain tendencies

[1] Lull, *loc. cit.*, p. 152.

[2] Lull, *loc. cit.*, pp. 152 and 188.

which have become tenaciously fixed in the human race that seem to have been the result of variation in a certain direction until these variations have become sufficiently accentuated to have survival value, while at the same time they have led to the development of certain diseases which are peculiar to civilized man thus forming a chapter in the pathologic phylogeny of man.

The geologic record has yielded a sufficient number of fossil remains of man to suggest the rough trail over which he has made his phylogenetic journey from the time he left the main highway of mammals. But the story of the rapid rise of man from this lowly origin is held not alone in the imperfect geologic record. Haeckel has provided us with the fact that ontogeny recapitulates phylogeny;[1] that is, that each individual recapitulates the story of his race, this record running parallel to the geologic record; and Darwin, in his *Origin of Species*[2] and in his *Descent of Man*,[3] accumulated many evidences in the structure of man of the effect of use and disuse of organs during his phylogeny. This would suggest the application of the principle of orthogenesis to the brain, the thyroid gland, and the hand, and to those organs and parts that are in consequence proportionately relieved of use.

One of the characteristics which separates man from the other mammalia is his incessant activity, especially mental and emotional. Both wild and domestic animals, as well as uncivilized man, secure food, procreate, play and sleep. Civilized man works all day and worries at night. The level of energy expenditure is one of the measures of the level of civilization. Primitive man is relatively inactive. Therefore, one would draw the inference that the evolution of man involved the brain, its tool, the hand, and equally the gland that governs the rate of metabolism, namely, the thyroid.

With a normal thyroid there is normal brain activity.

[1] Haeckel, E., *Generalle Morphologie*. Vol. II, Berlin, 1866. Cited by Lull, *loc. cit.*, p. 179.

[2] Darwin, C., *Origin of Species*. 6th Ed., London, 1872. Reprinted by D. Appleton & Co., New York, 1929, pp. 255 et seq.

[3] Darwin, C., *Descent of Man*. 2d Ed., London, 1874. Reprinted by A. L. Burt Co., New York, pp. 12 et seq.

With a defective thyroid there is defective brain activity. With excessive thyroid activity there is excessive brain activity. The thyroid hormone maintains the level of the activity of the brain.

One would expect the relative sizes of the thyroid, the adrenals and the brain to vary with the energy-characteristics of animals; that is, one would expect that the size of the thyroid would increase in proportion to the rate of constancy of demands for energy production while the size of the adrenals on the other hand, would vary with the need for sudden use of that energy. It would follow that the relative size of the thyroid would be greater in man than in other mammalia and that the adrenal glands, being the organs that govern the emergency energy output (Cannon), would be larger in the animals that depend on a rushing attack or a swift escape. Thus, according to the findings of Robert Crile, in collaboration with the Cleveland Museum of Natural History, in an examination of 137 animals, the adrenals are larger than the thyroid in the lion, the deer, the lynx, the peccary, in squirrels, rabbits and shrews, animals whose safety depends upon sudden outbursts of energy in fight or in flight. In these animals the weight of the adrenal glands is from two to three times the weight of the thyroid gland. In contrast, in man, in whom needs for the sudden output of energy are comparatively rare but in whom energy must be maintained at a high constant level throughout his life, the thyroid gland weighs approximately twice as much as the adrenal glands.

Contrariwise, we see in certain animals the development of passive defense mechanisms such as spines, shells, pungent odors, poisonous stings and bites. In animals in which these have developed there is a lack of development of the brain and special senses, of muscular power, of the thyroid and adrenal glands, presumably in accordance with the law of use and disuse, this lack of development being perhaps analogous to the lesser development in man of the organs of sight, hearing, taste and smell, of the teeth and jaws, of the muscles of the skin and of the ear, due to the fact that the cunning of the

brain, aided by the manipulative hand, through long periods of time, has relieved these organs of much of their exercise and use.

It would appear that the brain and the thyroid gland are undergoing a progressive evolution owing to the operation of the principle of orthogenesis, while the rest of the body, being less used, is slowly devolving as in the body of the porcupine, of the skunk, of the rattler, of the armadillo.

Dual Nature of Man

It would seem from the foregoing that the human organism is roughly divisible into two fractions.

One is the museum of man's antiquity consisting of the organs, tissues and functions that, being in senescence, are slowly disappearing, while, on the other hand, in accordance with the law of orthogenesis, we have the progressive evolution of the brain and of the thyroid gland.

Ontogeny and Phylogeny of Man

Between parents and offspring there is no break in the continuity of protoplasm as the plan and structure of the protoplasm of the parents are carried to the offspring in the protoplasm of the sex cells.

In this protoplasmic bridge there must exist the pattern of the heartbeat, of respiration and circulation, of locomotion, the exquisite nerve patterns of the sense organs, the pattern of the entire physical body; and growth, development and maturity are achieved from forces initiated within the human fetus. But this is not the case with the human part of the brain. The forces of growth within the fetus furnish only the blank matrix—a blank, undeveloped matrix upon which the action patterns or memories are to be recorded by means of training and education; that is, action patterns are imposed upon the matrix of the brain after man is born.

In the offspring of civilized man, just as in the offspring of lions and of antelopes and of monkeys, there is at birth a fully developed respiratory center, a circulatory center, a sucking

mechanism, the mechanism of the emotions, but the newborn babe has relatively a vastly greater mass of blank educable matrix upon which are to be recorded ontogenetic experiences.

The primitive mechanisms necessary to sustain life are developed first, as this early development of essential functions has survival value. If the early development of all the action patterns in the adult brain of man had survival value at birth, as in the case of many animals, then they would be present in man at birth. But in man there exists at birth, or is spontaneously developed, the function of every other organ and tissue of the body except the brain which presents a *blank* matrix. That the brain of a babe is blank at birth must be an adaptation.

Thus the characteristic difference between man and other animals lies in the large mass of blank matrix in which the multitude of patterns of action are recorded, thus enabling man to gain control over plants and animals and over the forces of nature. This conception enables us to understand that a bird is born knowing how to build a nest because the nest-building action pattern was in its protoplasmic bridge. It also enables us to understand that a boy is born not knowing how to build a house because in his protoplasmic bridge there was present only the blank matrix upon which the action patterns or education of how to build a house had to be later recorded from outside of himself. This, of course, makes it possible for the boy to build a better house than his grandfather because the ontogenetic experience of man is carried in current knowledge and craftsmanship and in books of science and literature; but it equally lessens the chance of the bird's ever learning to build a better nest.

Man came over the bridge with a large thyroid but a blank matrix in his brain. He did not come over the bridge with the multiplication table, with Latin and science, with the philosophies, religions and craftsmanship, nor did he come over the bridge with the action pattern of self-restraint. These are the threads of the web that civilization weaves. Ontogeny takes the blank matrix and records on it the web of

civilized man—and civilized man creates civilized man in his own image.

Effects of Racial Memories on the Organism

Racial memory extends far back in our history to the time when there was no shelter, no protection—when our ancestors had to settle their differences by physical struggle. In that day at the sight of danger there was a sharp dynamic division of the organism. The activity of those organs that were needed in flight or fight was accelerated, and a sharp inhibition of activity occurred in those organs that could contribute nothing to fight or flight, such as the processes of digestion and of procreation.

Man is beset by fears because of his racial memory mechanism, a mechanism that has made possible social and economic coöperation. This delicately poised social and economic relation is under constant strain. The driving force of fear and of its lesser form, worry, stimulates human beings to strivings, competitions, rivalries, and jealousies. The greatest and the most constant fear of man is fear of his fellow man. In the world of fears, worries, and anxieties in which civilized man is engulfed, he still fears just as the lower animals fear, largely in the physical terms of his ancestral fight or flight. The entire organism, as has been stated, is divided into two physiologic parts by flight or fight, causing a sharp inhibition of the digestive and procreative organs and a sharp stimulation of the nerve-muscular and circulatory mechanism. In other words, man fears with his brain, his thyroid, his adrenal-sympathetic system, in fact, with every organ and cell of his body. Therefore, man fears not intellectually but in terms of his ancient patterns of physical struggle, probably because his frontal lobe or memory brain, being a newcomer among the organs of the body, has not yet become fully adapted to his socialized status but responds according to primitive patterns.

The initiation of action is the function of the special senses and of memory. Though there is no physical danger, yet, upon receiving an adequate stimulus, the "memory brain"

throws the switches for full steam ahead, activating the muscles, the adrenals, the thyroid, the heart, the circulation and the respiration, and inhibiting simultaneously the digestive and procreative systems. No physical effort perhaps is involved, or at least is not initiated, yet the adrenals, the thyroid, the sympathetic system, the entire nervous system, each is raised to the level of the fight or flight stimulation, and the body-wide changes that take place constitute our emotions. Thus whether the organism is driven by the emotions or by physical struggle, every cell of the body is changed and charged and is taxed to its utmost.

Thus in a man or woman who is predisposed by birth and temperament to excessive fears, worries, and strivings, or who, though normally poised, is driven by misfortune excessively, permanent changes may be wrought. Just as by repeated repetition in school the action patterns of the brain of the school boy are created and subjected to a specific facilitation by his teacher in his training and education, just as repeated painful goadings facilitate pain, just as agreeable or disagreeable personalities facilitate attraction or repulsion, just as repetition produces habits, discontents, and familiarities, so repeated activations in the adrenal-sympathetic mechanism may cause such excessive facilitation that *normal* stimuli produce *abnormal* reactions. That is to say, there may be a process of training and education in *disease processes* analogous to training and education in Latin and mathematics. The nervous system may be facilitated or educated to disease as well as to health. Not only may the nerve pathways, nerve ganglia, synaptic junctions, be facilitated for either good or evil, but the cellular structure of the thyroid gland may grow in actual size and secure an increased capacity for work. That is to say, we may think of chemical training or education by repeated stimulation no less than of physical training or education by repeated stimulation.

In some such manner an hereditary predisposition played upon by adverse factors in the environment or in a normal individual under excessive strain, in one case may produce

hyperthyroidism, in another may pathologically sensitize the adrenal-sympathetic system producing neurocirculatory asthenia; in another may "step-up" the brain to its breakdown; in another may so facilitate the digestive mechanism in its *activations* and its *inhibitions* as to cause digestive disorders. Or the sympathetic ganglia may be so facilitated, so trained, that the resulting excessive flow of action currents to the walls of the blood vessels of the extremities leads to Raynaud's disease. On this principle we may interpret some of the brilliant invalids of history.

Thus we have sought an interpretation of certain unique diseases of civilized man in the field of phylogeny and ontogeny. We have indicated the adaptive relative size of the thyroid and the adrenal glands in species with contrasting characteristics—the collaboration and the entanglements of the racial past and the present status of man. We have pointed out that some organs of man are advancing, some stationary, some receding; that the high activity of the brain and the thyroid and of the adrenal-sympathetic system of civilized man gives him not only his unique powers and distinctions but also certain unique diseases.

THEORETICAL AND PRACTICAL STUDIES OF ATOMIC AND MOLECULAR FORMS OF THE HYDROGEN ISOTOPES

HUGH S. TAYLOR and HENRY EYRING

(*Read April 22, 1933*)

THE element hydrogen provides the best example with which the comprehensive development of our knowledge concerning the complexity of atomic and molecular species can be illustrated both theoretically and by actual experiment. Prior to the researches of Langmuir [1] in 1912 we recognized in the laboratory only one species of hydrogen, the molecule of mass 2, discovered by Cavendish [2] in 1766. Langmuir produced atomic hydrogen with the aid of high temperature tungsten surfaces and characterised its properties. Subsequently Cario and Franck [3] produced atoms by collisions of molecules with excited mercury atoms and Wood [4] produced atoms in the hydrogen discharge tube. Both methods led to further developments in our knowledge of the atomic species. On theoretical grounds, Heisenberg,[5] Hund,[6] and Dennison [7] each indicated in 1927 the existence of two forms of molecular hydrogen, respectively ortho and para hydrogen, isomers of differing nuclear spins. These two forms were experimentally confirmed in 1929 when Bonhoeffer and Harteck [8] indicated that, in contact with charcoal at liquid hydrogen temperatures, equilibrium was established between the two forms and that the position of equilibrium was practically pure para hydrogen. Taylor and Sherman [9] in 1931 showed that sur-

[1] Langmuir, *J. Am. Chem. Soc.*, **36**, 1708 (1914); **37**, 417 (1915).
[2] Cavendish, *Transactions of the Royal Society* (1766).
[3] Cario and Franck, *Z. Physik*, **11**, 161 (1922).
[4] Wood, *Proc. Roy. Soc.* (London), **102A**, 1 (1923).
[5] Heisenberg, *Z. Physik*, **41**, 239 (1927).
[6] Hund, *Z. Physik*, **42**, 93 (1927).
[7] Dennison, *Proc. Roy. Soc.* (London), **115A**, 483 (1927).
[8] Bonhoeffer and Harteck, *Z. physik. Chem.*, **4B**, 113 (1929).
[9] Taylor and Sherman, *Trans. Farad. Soc.*, **28**, 247 (1931).

faces at which activated adsorption of hydrogen occurs were extremely efficient in promoting the ortho-para conversion. On the other hand it appeared that van der Waals' adsorption at surfaces had little or no efficiency in promoting the change. It will be shown in the present communication that van der Waals' adsorption of hydrogen at paramagnetic surfaces leads to high conversion efficiencies in the ortho-para change.

Theoretical calculations based upon the discrepancies between the mass spectrographic atomic weight of hydrogen as determined by Aston [1] and the accepted chemical atomic weight led Birge and Menzel [2] to the conclusion that a heavy isotope of hydrogen of atomic mass 2 must exist in ordinary hydrogen to the extent of about 1 part in 4500 of the lighter isotope. By spectrographic examination Urey, Brickwedde and Murphy [3] established the existence of this heavy isotope but its concentration in ordinary hydrogen was estimated at 1 part in 30,000, a conclusion also reached by spectroscopic examination of the hydrogen chloride spectra by Hardy, Barker and Dennison [4] and by mass spectrographic work due to Bleakney [5] and Bainbridge.[6]

Washburn and Urey [7] next observed that the heavy isotope was concentrated in aqueous alkali solutions which had been used for long periods of time in the electrolytic production of hydrogen and oxygen. The preferential discharge of the lighter isotope at the electrodes was associated by us with the phenomenon of slow activated adsorption of hydrogen at surfaces and it was shown by Eyring [8] that the different zero point energies of the two hydrogen isotopes would accountt a least in part for the preferential electrolysis found by Washburn and Urey. These conclusions seem to be confirmed by the recent results of G. N. Lewis [9] on the production of pure

[1] Aston, *Proc. Roy. Soc.* (London), **115A**, 487 (1927).
[2] Birge and Menzel, *Phys. Rev.*, **37**, 1669 (1931).
[3] Urey, Brickwedde and Murphy, *Phys. Rev.*, **40**, 1 (1932).
[4] Hardy, Barker and Dennison, *Phys. Rev.*, **42**, 279 (1932).
[5] Bleakney, *Phys. Rev.*, **41**, 32 (1932).
[6] Bainbridge, *Phys. Rev.*, **41**, 115 (1932); **42**, 1 (1932).
[7] Washburn and Urey, *Proc. Nat. Acad. Sci.*, **18**, 496 (1932).
[8] Eyring, *Proc. Nat. Acad. Sci.*, **19**, 78 (1933).
[9] G. N. Lewis, *J. Am. Chem. Soc.*, **55**, 1297 (1933).

heavy hydrogen by the electrolytic method, by our own results using the same technique though differing in details and by the experiments of Taylor, Gould, and Bleakney [1] on the concentration of heavy hydrogen by fractional desorption of hydrogen from charcoal at liquid air temperatures.

In the following pages we shall present a summary of our theoretical and experimental work on the production of heavy hydrogen and an outline of our results on the ortho-para conversion at paramagnetic surfaces.

Heavy Hydrogen Isotope

Theoretical.—As has already been stated, the recent results of experiment using the electrolytic method of concentration convinced us that the explanation of the concentration effect was to be looked for in the relative reaction rates for the two isotopes and that the principal reaction involved, although certainly not the only one, is the rate of desorption of light and heavy isotopes at the electrodes. That there is such an effect is immediately apparent when we consider the following process:

A hydrogen ion approaching the cathode obtains an electron from the surface and then attaches itself to a surface atom A to form the oscillator H–A. This is followed by the reaction between two neighboring oscillators

$$2HA \rightarrow H_2 + AA \qquad (1)$$

to form hydrogen gas. For the vast majority of atoms, A, on a particular electrode, reaction (1) will involve an activation energy. This activation energy is approximately measured by the overvoltage if, as we suppose, the important slow process is the desorption. Reaction (1) consists in the two hydrogen atoms approaching each other and simultaneously receding from the surface in a symmetrical fashion, the reverse of the process of activated adsorption examined theoretically by Sherman and Eyring.[2] Such symmetrical

[1] Taylor, Gould and Bleakney, *Phys. Rev.*, **43**, 496 (1933).
[2] Sherman and Eyring, *J. Am. Chem. Soc.*, **54**, 2661 (1932).

configurations are completely specified by the distance between hydrogen atoms and the distance between the centers of gravity of the molecules H_2 and A_2. If for each set of values for these two distances we plot the energy of the configuration in a third dimension we get a three dimensional surface from which can readily be seen the path which the atoms follow in the desorption. This potential energy surface consists of a basin corresponding to the compound $\begin{matrix} H & H \\ | & | \\ A & A \end{matrix}$, separated from a long valley corresponding to the two compounds H_2 and A_2 by a low energy barrier. There are methods of calculating the nature of such surfaces [1] but the detailed shape need not concern us here.

In any case this potential energy surface is just the same whether the hydrogen atoms are the light or heavy isotope. For the reaction to take place the total energy must suffice for the system to cross over the barrier. Now, the least energy that the system composed of two H–A oscillators can have is the potential for the lowest point in the basin, increased by the sum of the two half quanta, the zero point energies, of the oscillators; so that the activation energy must be measured, not from the bottom of the basin, but from an energy higher than this by two half quanta. For most surface atoms the energy difference ΔE between the oscillators H^1–A and H^2–A is in the neighborhood of 1 kilogram calorie. The lighter molecule H^1H^1 will desorb approximately $e^{\Delta E/RT}$ times as fast as the molecule H^2H^1, where ΔE is the difference in the half quanta for H^1A and H^2A. For a nickel surface the difference in the half quanta is 0.68 kg. calories and the relative rates of desorption of H^1H^1 and H^1H^2 at 273°, 90°, and 20° absolute are 3.5, 43.5 and 2.34×10^7 respectively. One readily sees, therefore, why the light hydrogen should be liberated preferentially on electrolysis of solutions, and also the advantages of low temperatures. The corresponding figures for a charcoal surface are 1.1 kg. calories and 7.5, 500 and 1.3×10^{12} for the relative rates.[1] The measurements of

[1] Eyring and Sherman, *J. Chem. Physics*, 1, June (1933).

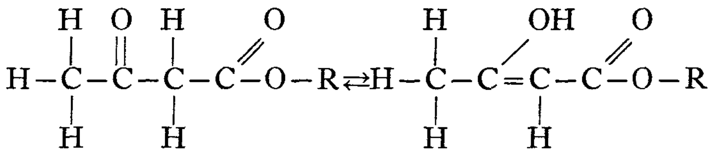
Taylor, Gould and Bleakney [1] show the expected concentration due to desorption from charcoal and may well provide one efficient means for the final concentration of the heavy isotope.

The figures given for the relative rates of electrolysis of light and heavy isotopes will be modified by such factors as the probable greater dissociation to form the light ion, any difference in the mobility of light and heavy hydrogen ions, the greater ease of acquiring an electron for the light hydrogen atom in the Gurney [2] sense. Finally, H^1H^1 and H^2H^1 may require, for two reasons, slightly different energies in passing the potential energy barrier. Firstly, because the lighter molecule may leak through the barrier somewhat more readily than the heavier one and secondly because the lighter molecule will have a slightly higher half quantum in the activated states. These last two effects tend to compensate each other. The observed relative rates of electrolysis on nickel are very close to those expected both as indicated by our own results and those Lewis informs us he obtained.

In a recent note Polanyi [3] singles out as most important the process in which the hydrogen ion sheds its sheath of water molecules before attaching to the electrodes. This is more rapid for the light isotope because it leaks more readily through the energy barrier as well as because of its higher zero point energy. Practically everyone seems agreed in attributing the separation to a difference in rates. Further experiments will show which stages in the electrolysis are critical for the separation in particular cases.

All systems will pass more slowly to equilibrium if the reaction in question involves heavy rather than light isotopes. We can illustrate the general difference to be expected in chemistry when H^1 is replaced by H^2 by considering the keto-enol isomerism.

[1] Taylor, Gould and Bleakney, *Phys. Rev.*, **43**, 496 (1933).
[2] Gurney, *Proc. Roy. Soc.* (London), **134A**, 137 (1931); **136A**, 378 (1932).
[3] Polanyi, *Naturwissenschaften*, **17**, 316 (1933).



In this reaction the only atom which need be considered as moving is the hydrogen atom which is first bonded to carbon and then wanders and becomes bonded to oxygen. The shifting of the double bond only involves the motion of electrons and because of their great mobility they continually take the position which gives the lowest energy to the system for each position of the hydrogen atom. If we plot distance along the three dimensional path which the hydrogen atom takes as abscissa and the energy of the molecule as ordinate we get figure 1. The keto form corresponds to the hydrogen

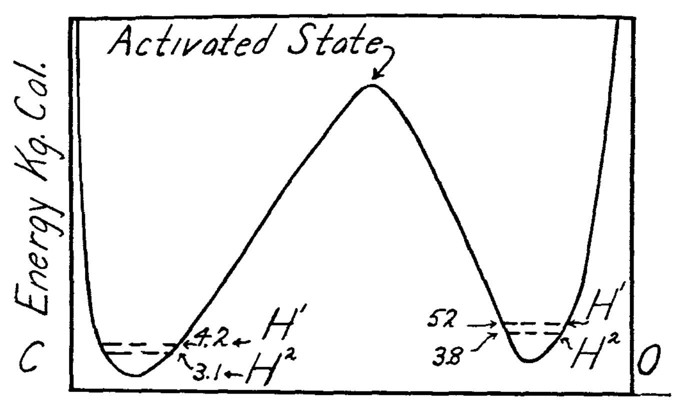


FIG. 1. Distance measured along the path followed by hydrogen in enolization process.

being in the position of the minimum on the left and the enol form corresponds to the minimum on the right. To pass from one to the other without catalysts involves an activation energy which both calculation and experiment indicate will require a somewhat elevated temperature. However, H^1 will have a zero point energy corresponding to the higher levels in the minima and H^2 to the lower levels. Thus the

compound with light hydrogen will enolize roughly seven times and ketonize approximately twelve times as fast as the heavy one at ordinary temperatures. Such relative rates of course depend exponentially on the temperature in the usual way.

Experimental.—In order to test these theoretical conclusions concerning the kinetic properties of heavy hydrogen, it is necessary to secure quantities of the pure heavy isotope with which to perform measurements of the rates of adsorption and reaction. The data of Taylor, Gould and Bleakney while demonstrating the efficiency of desorption for concentrating the heavy isotope did not seem to offer a practicable method for procuring large quantities of the heavy product without preliminary concentration by other methods. We therefore studied once more the electrolytic method of separation and devised a plan of operation capable of yielding in quantity water rich in heavy hydrogen concentration. Since our method differs in detail from others we will describe it briefly.

Our starting material was electrolyte liquor (NaOH) kindly supplied to us by the Paschal Oxygen Co. of Philadelphia through the courtesy of the Vice-President Mr. A. Roy Robson. This liquor was from cells which had been in continuous use since 1918 and could therefore be expected to have attained the steady state concentration of heavy isotope. It is perhaps worth emphasizing that, as normally operated, electrolytic cells will not yield more than a certain enrichment of heavy isotope. A stationary concentration is reached after which the heavy hydrogen lost in the electrolytic gas, but more especially in the accompanying saturated H^2 rich water vapor and spray, exactly equals that fed into the system as feed water. It is this circumstance which dictates the special procedure of enrichment to be adopted which finally yields the heavy water desired.

We distilled the commercial electrolyte, using the technical equipment of the Princeton Chemical Engineering Laboratory, through the courtesy of Professor J. C. Elgin, in order to

eliminate the large amounts of carbonate and hydroxide present and started our own electrolyses with solutions 0.5 molar with respect to KOH or NaOH made from the distillate. Our first electrolysis was effected in a battery consisting of 7 units each of 30 cells operating with current from a variable voltage motor generator, normally at 110 Volts D.C. and 8.5 amperes per unit. The cells were made up of tall cylindrical vessels, of 200 cc. capacity, approximately 25 cm. high, a strip of nickel plate 60 cm. long and 3 cm. wide, bent twice at right angles forming anode and cathode in neighboring cells. With these seven units we can electrolyze approximately nine gallons of electrolyte in two days to approximately 1/6 its initial volume. The electrolyte is then removed, an aliquot portion set aside, the remainder distilled, and the whole employed to initiate a second electrolysis, with the liquor again 0.5 molar with respect to the electrolyte, in a unit similar to the 7 units already described, but with fewer units and the appropriate voltage, each successive electrolysis effecting an approximately two-fold concentration of the heavy isotope. At a suitable stage the hydrogen from the electrolysis is sufficiently rich in heavy hydrogen to make it worth while to reconvert the hydrogen to water and return it to the electrolysis at the appropriate point. Thus 5 per cent heavy water yields hydrogen containing approximately 1 per cent heavy hydrogen. Operating in this manner no heavy hydrogen need be lost in the later stages of the process. This may be achieved either by burning both oxygen and hydrogen at a suitable surface or by burning the hydrogen in a stream of air over copper oxide, condensing the water vapor formed at the temperature of carbon dioxide snow.

In our initial run, with no efforts to recover hydrogen, we obtained from our first 20 gallons of old electrolyte, 120 cc. of water containing 5 per cent of the heavy hydrogen isotope. Actually this represents only a low operating efficiency so far as the heavy product is concerned and we have now taken steps to increase considerably this efficiency.

Our experiments on the properties of the heavy hydrogen,

its reaction velocities with various adsorbing surfaces will be reported later.

Ortho-Para Conversion of Ordinary Hydrogen at Paramagnetic Surfaces

Chromium oxide has been shown by Mr. J. Howard in this laboratory to adsorb hydrogen by van der Waals' forces below 0° C. and by activated adsorption with increasing velocity above 0° C. We were surprised, therefore, in view of the earlier data of Taylor and Sherman,[1] to find that at liquid air temperatures, where the adsorption is exclusively of the van der Waals' type, a rapid ortho to para conversion occurred.

In view of analogous reports as to the effect on iron-ammonia catalyst surfaces as detailed by Harkness and Emmett,[2] and also at the Washington A. C. S. meeting in March 1933, we were led to investigate, with Mr. H. Diamond, of this laboratory, a whole series of substances of known diamagnetic or paramagnetic susceptibilities. Our work has conclusively shown that rapid conversion to para-hydrogen at liquid air temperatures with van der Waals' adsorption only involved is to be associated with the paramagnetic properties of the surface. Chromium oxide, a crude cerium oxide containing neodymium oxide, a pure sample of neodymium oxide, gadolinium oxide, vanadium oxide V_2O_3, a mixture of zinc and chromium oxides with marked paramagnetic susceptibility, and magnetic oxide of iron all show the ability to convert rapidly the 1 : 3 ortho-para mixture to the equilibrium 1 : 1 mixture. The speed varies from case to case dependent in part on the susceptibility and also on the extent of surface condensation of the hydrogen. The quantitative aspects are under investigation. Diamagnetic oxides such as zinc oxide, lanthanum oxide and completely oxidised pure cerium dioxide show only small conversions with contact times extending to hours as compared with equilibrium con-

[1] Taylor and Sherman, *Trans. Farad. Soc.*, **28**, 247 (1931).
[2] Emmett and Harkness, *J. Am. Chem. Soc.*, **54**, 403 (1932).

versions over the paramagnetic substances in flowing gas systems at space velocities as high as 1000 cc. per gram of catalyst per hour in the case of a substance such as chromium oxide gel with high surface extension.

This function of paramagnetic surfaces is paralleled by the effect of paramagnetic gases such as oxygen, nitric oxide, nitrogen peroxide which have recently been reported by Farkas and Sachsse [1] as effecting the ortho-para conversion in homogeneous systems. In an appendix to their publication is a reference to a theoretical treatment of this problem from the standpoint of wave mechanics by Prof. E. Wigner. His conclusions are of interest in the present work and will be subjected to further experimental test.

Frick Chemical Laboratory,
Princeton, N. J.

[1] Farkas and Sachsse, *Sitz. der Preuss. Akad. der Wiss.*, **6**, 268 (1933).

PROGRESSIVE CHONDRIFICATION IN THE STEGOCEPHALIA

ERMINE C. CASE

(*Read April 21, 1933*)

EVIDENCE that the phylogenetic development of the Stegocephalia was in the line of a reduction of the ossifications of cartilaginous origin in the basicranial and otic regions and a resumption of the importance of the bones of dermal origin in the skull has been gradually accumulating but has not been gathered together, and no direct account of the stages in this phylogenetic process has been given. The original and legitimate assumption that the progress from the fish to the reptile was through an amphibian stage with an ever increasing degree of ossification of the skeletal elements has only slowly been proven erroneous. It now seems worth while to give a synoptic and categorical statement of the evidence.

It is now apparent that the duration of the Amphibia as a distinct step in the progress of the vertebrates and as a link connecting the fishes with the reptiles was very brief in terms of geological time, and the conclusion that the appearance of the Amphibia and Reptilia was almost contemporaneous is being forced upon us.

The work of Götte, Williston and Watson has demonstrated that the embolomerous type of amphibian vertebrate is the most primitive of the three types which can be shown to be phylogenetically connected. There seems to be warrant in usage for including the Temnospondyli (Embolomeri and Rhachitomi) and the Stereospondyli under the name Labyrinthodontia. If the peculiar course of development here emphasized be accepted as characteristic of the group, the name may be reëstablished with a useful meaning. In any case it is proposed to use the name tentatively in this paper to distinguish these three groups from the other groups of

Stegocephalia and to avoid troublesome repetition. The history of the other groups is still too imperfect to permit their inclusion in the argument and the evidence presented will be derived from the Labyrinthodontia only. However, it seems certain that the other groups have passed through a similar history, the effects of which are noticeable in the living forms of today.

The various steps in the establishment of the fact that the embolomerous forms were the earliest to appear and the most primitive in structure have been reviewed by Watson (1926), who assembled the evidence, so far as it was then known. To his work can now be added much pertinent material for the early stages (Säve-Söderberg, 1932) and for the latest stages (Case, 1931 and 1932). Though the evidence is most striking in the changes shown in the skull, confirmatory evidence can be drawn from the increasing chondrification of the axial skeleton and from the resumption of importance by the bones of dermal origin. The evidence presented here must be confined to that furnished by the skull.

In this paper the best known genera have been selected as typical of the stages of development through geological time. A more extended discussion would show that most other forms, only partially known, can be fitted into their proper position in the series.

There is uniform agreement that the amphibians rose from some form of Crossopterygian fish and fortunately we have very complete descriptions of the skulls of some of these. Bryant (1919) has described *Eusthenopteron* and Watson (1921) has described the skull of certain Cœlacanths. From a skull of this type was developed the well ossified skull of the primitive amphibian and from that to the time of the extinction of the Labyrinthodonts the history is one of continuous chondrification. The author designedly refrains from using the term degeneration in this connection as the process seems to have been one, rather, of progressive development.

Watson (1926) has listed the changes involved in the chondrification of the skull as follows:

"The skull and the anterior part of the body show a progressive flattening reaching an extreme in such creatures as the Upper Triassic *Metoposaurus*, where the neck and the occiput is more than twice as wide as it is high.

"The brain case becomes progressively less well ossified, and the basioccipital, basisphenoid, and supraoccipital bones become reduced in thickness and finally disappear even as cartilage. The original tripartite condyle thus giving place to a pair of well separated exoccipital condyles.

"The cavity in which lies the fore-brain is excavated in the upper part of a thick interorbital septum in all early forms. In later times it extends further downward, until finally it comes to rest on the dorsal surface of the parasphenoid; the originally tropibasic skull being thus converted into a platybasic cranium of modern Amphibian type.

"The interpterygoid variations (interpterygoid space) steadily become larger, until they recall those of the frog. In association with this change the pterygoid, instead of articulating in part with a basipterygoid process of the basisphenoid, comes to depend entirely on the parasphenoid for its support.

"The epipterygoid, which in the Lower Permian forms is a small bone resting on the pterygoid and basipterygoid process, and provided with a processus ascendens alone, gradually grows upward into an otic process which acquired an attachment to the pro-otic."

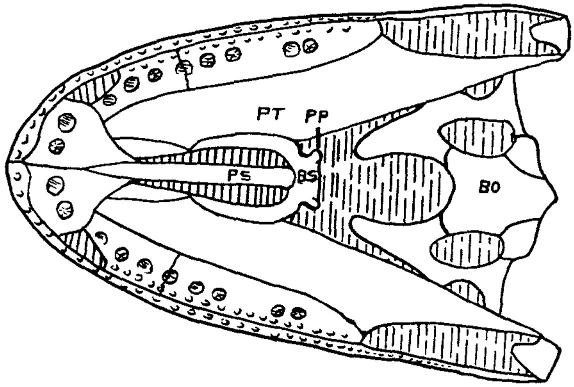
To these must be added for the Upper Triassic Stereospondyli:—reduction, and probably complete disappearance, of the proötic and the reduction of the epipterygoid to small proportions, the total disappearance of any bony protection of the otic capsule, and the disappearance of the original bony walls of the brain case and their replacement by rising processes from the upper surface of the quadrate rami of the pterygoids.

Figures 1 and 2 show the condition of the brain case and ethmoidal region in *Eusthenopteron* from the upper Devonian of Scaumenac Bay, Quebec, as figured by Bryant and Watson. Its stratigraphic position is regarded as equivalent to that of the Old Red Sandstone of Scotland.

While the skull of none of the well known fossil Crossopterygia can be compared directly with the skull of the living

Polypterus there is enough of similarity in the general plan to confirm the conclusions drawn from the fossils. In both, the brain case and ethmoidal region are well ossified but separated by a considerable space filled during life by cartilage, and bridged by the sphenethmoid bones on the sides of the fore-brain.

In *Eusthenopteron* the basioccipital is well developed and



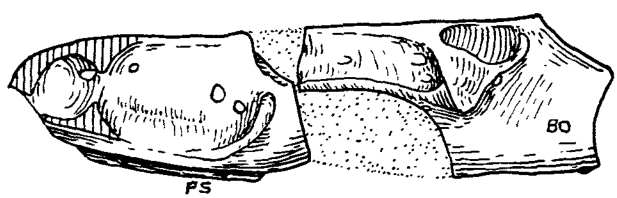


FIG. 1. Palatal surface of skull of *Eusthenopteron*. After Bryant. Figures have been reduced to a comparable size. Lettering for all figures: *BO*, basioccipital; *BS*, basisphenoid; *EO*, exoccipital; *EP*, epipterygoid; *PP*, pterygoid process; *PS*, parasphenoid; *PT*, pterygoid; *ST*, stapes.

FIG. 2. Lateral surface of skull of *Eusthenopteron*. After Bryant.

shares with the exoccipitals in the formation of a deeply cupped condyle.

The basisphenoid is well ossified and carries distinct basipterygoid processes which articulate with the pterygoids, and support, in part, the epipterygoids.

The parasphenoid is a thin plate underlying the basi-sphenoid which lies anterior to the cartilaginous region.

The pterygoids are large bones which approach fairly close to each other, leaving but a small interpterygoid space.

The cranial region is supported by a compact occipital element composed of the basioccipital and the exoccipitals. There are distinct opisthotic and proötic bones sheltering the membranous labyrinth. There is no fenestra ovalis and neither stapes nor columella, differentiated as such.

In *Megalicthys* the pterygoid complex is, according to Watson (1926, fig. 33), composed of epipterygoid, pterygoid and three small, mesially placed bones described as suprapterygoids. These last occupy the position of the cartilaginous plate described by Shuskin (1928) as reaching from the epipterygoid to the quadrate and shown by him to persist even in the primitive Reptilia, *Cotylosauria.* The same suprapterygoid bones are found in *Eusthenopteron* but with a slightly different arrangement (Watson, 1926, fig. 34); the persistence of this cartilage even in the Upper Triassic Stegocephalia is shown by the presence of the strong cartilaginous attachment on the anterior face of the quadrate in *Buettneria* (Case, 1932).

The vestibular portion of the ear was sheltered in a cartilaginous extension from the exoccipital or the proötic.

The gap between the nearest Crossopterygian fish, *Sauripterus*, and the most primitive Stegocephalian has not been bridged by discovered specimens but we may be certain from the near approach upon the two sides that the intermediate stage was not greatly different from that of the known Rhizodont Crossopterygia, in the essentials of structure.

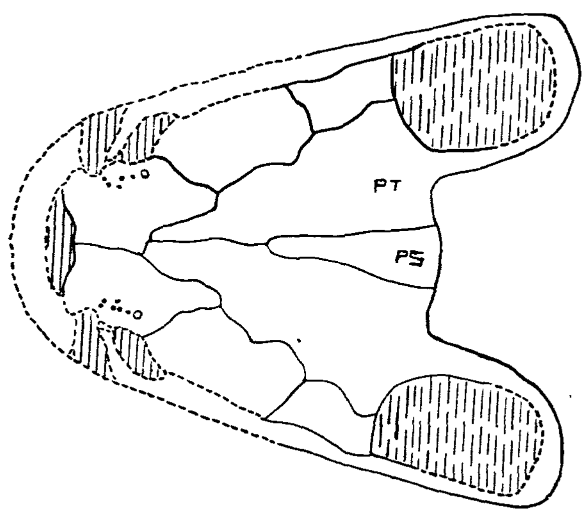
Säve-Söderberg (1932) has given a preliminary description of a collection of very primitive Stegocephalians from the upper Devonian of Greenland. These, his *Ichthyostegalia*, approximate very closely to the Crossopterygia in such details of the skull as have yet been made known. He has described two genera, *Ichthyostega*, with three species, and *Ichthyostegopsis*, with two species. The evidence derived from these specimens is mutually confirmatory and adds new evidence connecting the two classes, as the state of ossification

and the topographical relations of the cranial bones are directly derivable from the Crossopterygia and closely prophetic of the condition of the embolomerous Labyrinthodonts of the succeeding Mississippian period.

As shown in figures 7 and 12 of Säve-Söderberg's paper the skulls of *Ichthyostega eigili* and *Ichthyostegopsis wimani* are considerably elevated; it is probable that all of the Ichthyostegalia retained this primitive character.

The basioccipital and the condyles are as yet unknown.

The most striking change in the skull from that of the Crossopterygia is that the ethmoidal and cranial portions are in contact; the large mass of intermediate cartilage has disappeared (see figures 3 and 4).



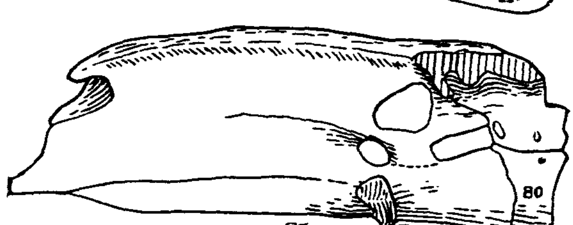


FIG. 3. Palatal surface of skull of *Ichthyostega*. After Säve-Söderberg.
FIG. 4. Lateral surface of skull of *Paleogyrinus*. After Watson.

The basisphenoid is large and has well developed basipterygoid processes.

The parasphenoid has broadened and nearly fills the interpterygoid space. Its extent to the rear over the basioccipital is not determinable but it must have underlain a portion of it, at least.

The pterygoids are broad plates reaching far forward and meeting anterior to the parasphenoid.

The epipterygoid must have been supported in large part by the basipterygoid processes and the pterygoids.

The otic region is not described but there is evidence that the region was well ossified with bony protection for the semicircular canals, at least.

A most interesting fact connecting these forms, which so closely resemble the embolomerous forms from the Mississippian of England, with the Crossopterygia is the position of the external nares, which are either upon the lower surface of the skull or notch its rim. Though no portion of the post-cephalic skeleton has been described every implication of time and structure leads to the conclusion that the Ichthyostegalia had embolomerous vertebræ.

The next stage in the chondrification of the skull is shown in the embolomerous forms described by Watson (1926) from the Mississippian and Pennsylvanian of England. In *Eogyrinus*, *Paleogyrinus* and *Loxoma* (*Orthosaurus*) the changes are notable. The external nares have attained the usual position on the surface of the skull and the bones of the roof are normal in number, position, and arrangement.

In *Loxoma*, figure 5, the skull is still relatively high.

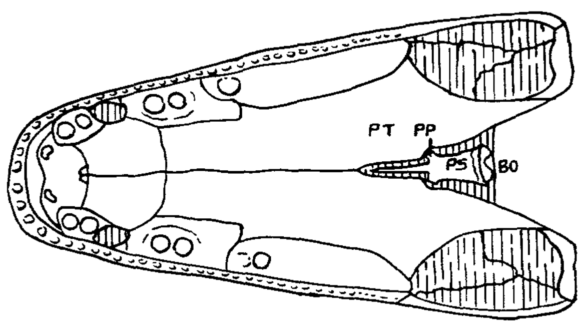
The basioccipital is not covered by the parasphenoid and the condyle is cup-shaped, formed by the basioccipital and the exoccipitals.

The basisphenoid is well ossified and carries well developed basipterygoid processes but the parasphenoid has spread out below the processes and may share in the support of the epipterygoid.

The parasphenoid is still narrow and extends forward as a slender process in the interpterygoid space.

The pterygoids are large and form most of the palatine surface, meeting anterior to the parasphenoid. The inter-pterygoid space is narrow.

The opisthotic and proötic bones are well ossified and shelter the membranous ear. There is no fenestra ovalis but its formation is foreshadowed. Watson says of this region (1926, p. 205):



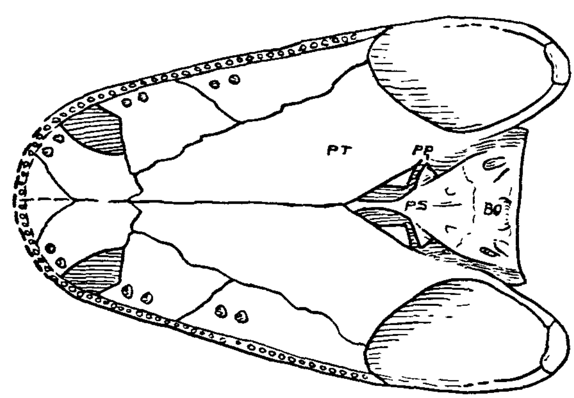


FIG. 5. Palatal surface of skull of *Loxoma*. After Watson.
FIG. 6. Palatal surface of skull of *Macrerpeton*. After Romer.

"In *Osteolepis*, the internal ear is known to have a very simple arrangement of semicircular canals, the vestibule opening into the cranial cavity by an aperture of considerable but not very large size. The cavity for the saccular part of the labyrinth is large and part of its outer wall appears to remain unossified. The hyomandibular articulates with the paroccipital process nearly in contact with the skull roof, and as in the majority of the teleostomi is perforated by

a canal for the passage of the hyomandibular branch of the VIIth nerve. The so-called jugular vein passes through a canal which perforates the paroccipital process.

"The region where a fenestra ovalis would be expected is only known in two Embolomeri, and in each case there is complete evidence to show that no such opening occurs. The pro- and opisthotics bear a deep pit on their suture in the proper position, but this is closed by a thick floor of bone. In one Embolomerous form a stapes is shown in position, it is a short curved rod of bone, more than a centimeter wide and 5 mm. thick, which stretches from the otic capsule upward and outward until it ends in the otic notch, flush with the general outer surface of the head. Its presence shows that a tympanic membrane had already been developed, and that the sense of hearing was already in existence. But this stapes lies at right angles to the direction of the hyomandibular of fish, and articulates much lower down on the otic capsule.

"There is, however, in all the members of that group of Embolomeri which includes *Loxoma*, a curious pit on the quadrate, so placed that it faces toward the otic capsule which must have housed some structure. This can only have been a cartilaginous process from the stapes, representing the lower part of the hyomandibular.

"The living reptiles exhibit a curious four-rayed columellar apparatus, one leg passing inward to the fenestra, the opposite one to the tympanic membrane, a third goes downward to the hyoid, and the fourth is attached to the end of the paroccipital process—that is, it occupies the position held by the head of the hyomandibular in *Osteolepis*. I believe the process to have been present in the Embolomeri, and that both it and the footplate of the stapes represent the original head of the hyomandibular divided into two by an enlargement and migration upward of the hyomandibular foramen, the inner of the limbs so formed migrating downwards over the jugular canal to its final position.

"The fact that a tympanic membrane connected to the otic region by a stapes can be formed before formation of a fenestra ovalis is an astonishing one, perhaps most readily understood if it originally took place in the water, where the amount of energy which can be conveyed by sound waves of reasonable amplitude is greater than in the air."

In *Eogyrinus* and *Paleogyrinus* the parasphenoid is broader and extends as a thin film back beneath the basioccipital (see figure 4).

The otic region of *Paleogyrinus* is described and figured by Watson (1926, p. 216, fig. 12).

"The posterior end forms a single deeply concave condyle, agreeing exactly with the end of an embolomerous centrum in structure. The lower surface of the bone is cylindrical, its hinder border forming the margin of the condyle. The upper surface posteriorly bears two facettes for the exoccipitals, which do not meet, so that the bone forms the middle part of the floor of the posterior part of the brain cavity. The bone is shown to run forward and to articulate with the basisphenoid.

"The basi- and parasphenoids are fused, but can be distinguished by slight differences in the texture. The parasphenoid covers the greater part of the lower surface of the basioccipital, overlapping the sides of that bone nearly to its articulation with the otic bones. In front of the otic region the joint bone bears a pair of well-formed basipterygoid processes which project laterally and somewhat downwards. The lower surface of each process at its root has a groove passing from the posterior round on to the anterior surface; this housed the internal carotid artery. The outer end of the process bears an articular face looking forward and outward, which surface is rather obscurely divided into an upper part directed a little dorsally, for the epipterygoid, and a lower for the pterygoid. . . .

"The lateral surface of the otic region rises smoothly from that of the basioccipital; just above its suture with that bone at a point about one centimetre in front of the vagal foramen, it is abruptly excavated by a deep pit, whose bottom is shown to be closed by bone on both sides of the specimen. From this pit the apparent suture which bounds the pro-otic arises; in other words, the pit lies on the suture between the pro-otic and paroccipital, the basioccipital forming part of its lower wall."

Among the Pennsylvanian embolomerous forms of America, *Macrerpeton* is restored by Romer (1930, fig. 21), see figure 6 of this paper. Romer remarks concerning this form that there is an anterior lateral bone distinct from the frontal which he is unable to account for; it is worthy of note that this bone is in exactly the position and relations of the bone called anterior antorbital by Säve-Söderberg in the Ichthyostegalia, bordering the external nares above. As the nares are not preserved in the specimen of *Macrerpeton huxleyi* de-

scribed by Romer it is possible that this genus retained the primitive position of the nares and the bordering bone.

The skull of *Macrerpeton* is still relatively high.

The basioccipital is well developed and the "condyle is of the primitive type, a single subcircular cavity, mainly formed by the basioccipital, but with the exoccipitals entering into the dorso-lateral parts."

The basisphenoid is still ossified with large basipterygoid processes "large and quite thick facing anteriorly and somewhat ventrally."

The parasphenoid is broad anteriorly, beneath the frontals, and narrows rapidly as it passes backward; it does not cover the basioccipital, for Romer says the posterior boundary may be traced across the ventral surface.

The pterygoid is "large and broad anteriorly, and although a median suture between the two sides is seen for only a short distance, the interpterygoid vacuities were obviously very small."

The bones of the otic region are not differentiated but form an ossified wall rising toward the surface of the skull. There is a small depression in the proper place which represents the fenestra ovalis.

Romer places *Macrerpeton* among the rhachitomous forms but considering its many resemblances to the English Embolomeri, Woodward (1932) is in all probability right in placing it within that group.

In the Permo-Carboniferous the history of the process of chondrification is complicated by the first obvious separation of the Labyrinthodonts into a more terrestrial group and a more aquatic group. It is not to be doubted that this separation began in the Pennsylvanian or earlier, but the evidence for the two lines of development is first demonstrable in the late Paleozoic. Both the Embolomeri and the Rhachitomi occur in the Permo-Carboniferous but the first group is less abundantly represented and is apparently on the decline. No specimen of the North American Embolomeri is known which shows the details of the basis cranium or the

otic region, but the known portions of the skulls and jaws of *Cricotus* and *Cheneprosopus* show striking similarities to the same parts of *Paleogyrinus*. Two specimens of *Cricotus* in the collection of the Museum of Paleontology of the University of Michigan show the under surface of the roof and these are almost identical with the same region in *Paleogyrinus* as figured by Watson (1926, fig. 19). The lower jaw of *Cricotus* is much like that of *Paleogyrinus*. In *Cheneprosopus* as figured by Mehl (1913, fig. 5) the skull was still relatively high and the pterygoids large and closely approximated.

The Rhachitomi are more abundant and in both the terrestrial and the aquatic forms show the first well defined opening of the palate by reduction of the pterygoids in the Labyrinthodontia, a condition which had already reached an advanced stage in the Phyllospondyli in the Pennsylvanian period.

The terrestrial branch is best understood in *Eryops*, *Actinodoa* and *Sclerocephalus* from North America, France and Bohemia, respectively. In these the skull shows the broadening and depression which becomes so marked in the Triassic stereospondylous forms (see figures 7 and 8).

The basioccipital is reduced to very small proportions or is absent and the condyles are separated and formed by the exoccipitals only.

The basisphenoid is present but smaller with reduced but still distinct basipterygoid processes.

The epipterygoid is present (*Eryops*) as a slender rod resting upon the pterygoid in large part.

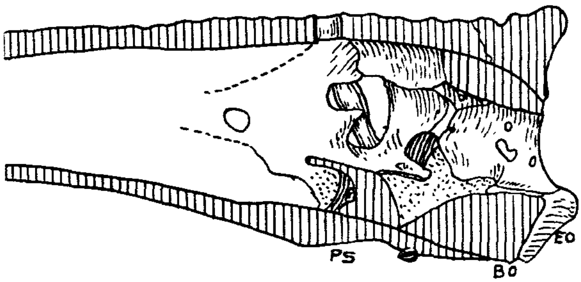
The cultriform process of the parasphenoid reaches far forward but does not reach the prevomers; the posterior portion reaches far back towards the posterior edge of the skull so that the basioccipital is covered or nearly so. It underlies completely the basisphenoid.

The pterygoids are much reduced, slanting outward and forward leaving a large interpterygoid space, and no longer meet anterior to the parasphenoid.

The otic region is well ossified as a periotic mass (opisthotic

+ proötic) which shelters the semicircular canals. The fenestra ovalis is open and there is a well developed stapes.

Actinodon corresponds closely to *Eryops* in structure. Gaudry (1887) figures the posterior portion of the lower surface of a skull, found at Dracy-Saint-Loup, which shows the parasphenoid extending almost to the posterior end with



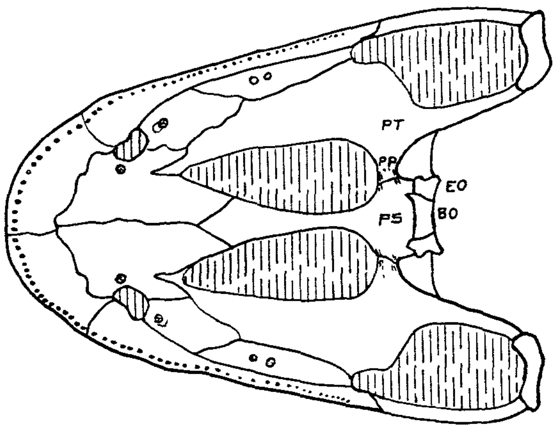


FIG. 7. Median section of skull of *Eryops*. After Watson.
FIG. 8. Palatal surface of skull of *Eryops*. After Watson.

well developed basipterygoid processes shared by the parasphenoid and basisphenoid. He describes the parasphenoid as united with a very short element (basilare) which carries two occipital condyles and his figure shows a decided termination of the parasphenoid posteriorly on the under side of the basioccipital. He further describes, however, the cartilaginous condition of the posterior end of the basicranial axis

and says that the condyles appear as bony elements only late in the ontogeny and that there was evidently a median cartilaginous segment in his basilare (basioccipital + exoccipitals). Considering that the specimen is repeatedly described as covered by a thin layer of shale which cannot be removed, and the state of our knowledge at the time the description was written, it is safe to regard the basioccipital as much reduced and covered by the parasphenoid, as in *Eryops*.

The aquatic group of the Rhachitomi is best represented by *Trimerorhachis* from North America and *Lydekkerina* from South Africa. This group is apparently near the direct line of descent of the Stereospondyli.

The skull is much broadened and is quite flat.

Trimerorhachis retains a decidedly primitive feature in that the basioccipital takes part in the formation of a cup-shaped occipital condyle. The bone is short, however, and the anterior portion has become chondrified.

The basisphenoid has not been found and Broom (1913) was of the opinion that it was completely unossified.

The parasphenoid extended nearly to the posterior end covering and articulating with the basioccipital; it has articular processes for the pterygoids. The anterior end reached to the prevomers and the sphenethmoid is greatly reduced or absent.

The pterygoids are slender and far apart, leaving a large interpterygoid space.

Broom recognized distinct opisthotics and proötics which are closely articulated and says that the "inner sides of both otic bones are somewhat excavated for the reception of the membranous labyrinth, and it is pretty certain that the whole region (otic capsule) has remained cartilaginous."

Lydekkerina is described by Watson (1919).

The basioccipital is described in one place (Watson, page 13) as a bone "exposed in the median line between the parasphenoid and the foramen magnum (which) is presumably the basioccipital, but (with) no suture separating it from the

exoccipitals." And in another place, a few lines below, he describes the exoccipitals as sending processes inward which form the floor of the foramen magnum and "roofing a little cavity in which the basioccipital cartilage formerly lay." The condyles are borne upon the exoccipitals.

The basisphenoid is not preserved and apparently was completely chondrified.

The parasphenoid does not extend to the posterior edge but near it unites by suture with the exoccipital (basioccipital?) element described above. There is no suggestion of basipterygoid processes, the bone uniting by close suture with the pterygoids.

The pterygoids are small and separated by a large interpterygoid space.

There is a small but distinct opisthotic sheathed by the exoccipital. It is far too much reduced to have sheltered any portion of the membranous labyrinth. The otic cavity is bounded by the exoccipital and the parasphenoid.

In the Stereospondyli is found the culmination of the process of chondrification.

In *Capitosaurus* from the Triassic, the skull, as in all of the stereospondylous forms, is very flat. The specimen described by Watson (1919) is from the Cynognathus zone of South Africa (see figures 9 and 10).

The basioccipital is reduced to a very small rudiment and completely covered by the parasphenoid. The condyles are borne by the exoccipitals, which are separated by a considerable space occupied during life by the cartilaginous basioccipital.

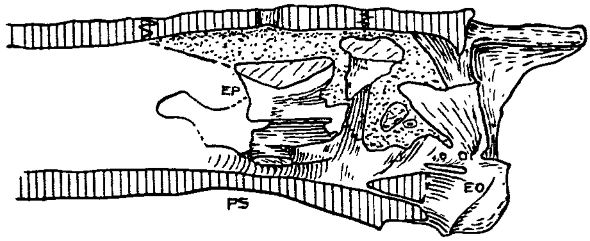
The basisphenoid is much reduced and all traces of the basipterygoid processes have disappeared, the bone being united to the pterygoids by close sutures.

The epipterygoid is still fairly large, it rises from the pterygoid and the parasphenoid.

The parasphenoid covers the entire basicranial surface, extending to the posterior edge of the skull.

The interpterygoid space is very large.

The opisthotic has disappeared and the proötic is far forward. In this form for the first time is seen the rising process on the upper face of the quadrate ramus of the pterygoid. As shown by Watson (fig. 12, 1919), it rises mesially to the proötic (figure 10). The space occupied by the cartilaginous capsule of the ear is bordered by the ex-occipital and the parasphenoid behind and below, by the



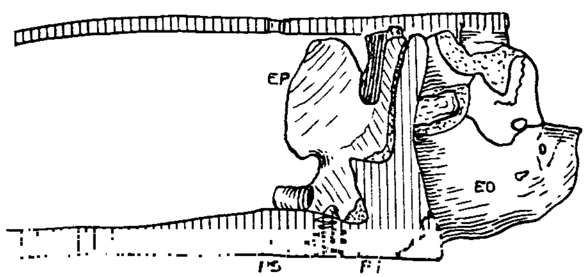


FIG. 9. Median section of skull of *Capitosaurus*. After Watson.
FIG. 10. Lateral surface of skull of *Capitosaurus*. After Watson.

tabulare above; and, perhaps, by the rising process of the quadrate in front.

In *Buettneria* from the Upper Triassic of North America the chondrification reached its final stage before the extinction of the Stegocephalia (Case, 1931 and 1932).

The skull has reached the extreme of flatness.

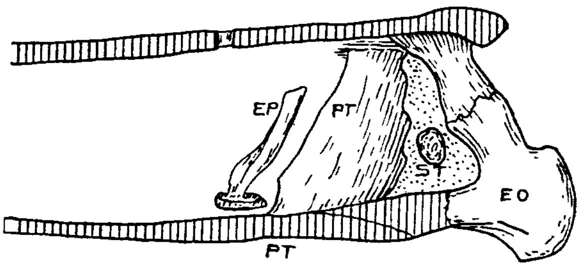
The basioccipital is unossified; the condyles are borne upon the exoccipitals which are separated by a large space occupied in life by the basioccipital cartilage.

The basisphenoid has entirely disappeared, there is no trace of even a cartilage. The bone is closely united with the pterygoids by suture and all trace of the basipterygoid process has disappeared.

The epipterygoid is reduced to small size and rests upon the pterygoid.

The interpterygoid space is large, perhaps the largest, proportionately, of any of the Labyrinthodonta.

The opisthotic has entirely disappeared. The proötic has either disappeared or is represented by a small rudiment attached to the anterior end of the rising process of the quadrate ramus of the pterygoid. With the disappearance of all the bones originally sheltering the membranous labyrinth the otic capsule is entirely cartilaginous and lies in a large



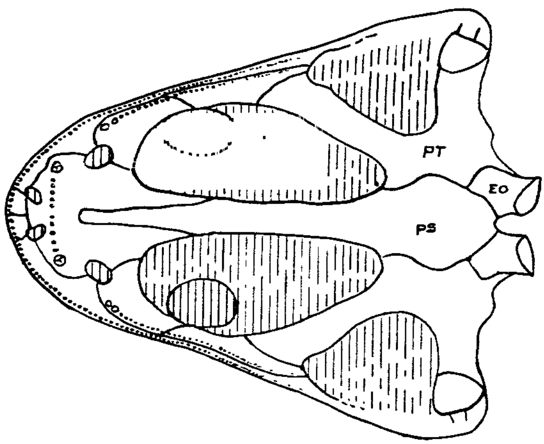


FIG. 11. Section of skull of *Buettneria* to one side of the median line. After Case.
FIG. 12. Palatal surface of skull of *Buettneria*. After Case.

space outlined by the pterygoids, exoccipital and the tabular (figures 11 and 12).

The rising process from the upper side of the quadrate

ramus of the pterygoid is developed into a prominent plate supplying the function of the otic bones in forming the lateral walls of the brain case.

These typical and well described forms selected from the successive geological periods and stages of chondrification show very clearly the course taken by this branch of the Stegocephalia. Numerous variations in form and proportions of the skull have been described but all show the same continuous development. The process is shown only less strikingly in the weakening of the limbs and girdles, with a concomitant strengthening of the dermal elements, the clavicles and interclavicles, which attain the maximum of size and strength in the latest genera. The forms which show the continuous changes best were aquatic and the reversal of the tendency to a development of a more strongly braced skull by the growth of the cartilage bones of the skull, and a return to the protection and support afforded by the strengthening of the dermal bones is perhaps to be connected with this habitat and the peculiar habits and structure of the Amphibia.

Though the process is best illustrated in the Labyrinthodonts it was at work in all the other branches of the class and the peculiarities of the skull of the living Amphibia are directly attributable to the same history.

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THE FISH FAUNA OF BEARTOOTH BUTTE, WYOMING

WILLIAM L. BRYANT

(Read April 21, 1933)

PART I. THE HETEROSTRACI AND OSTEOSTRACI

IT IS a far cry across the hundreds of millions of years that separate even the oldest human and semi-human fossil remains from those of their most primitive ancestors, the lowest vertebrates. Yet of late years we have acquired a really astonishing amount of detailed information concerning the anatomy of those earliest of vertebrates, the predecessors of the true fishes.

A large number of new forms among the Ostracoderms have recently been discovered, both here and abroad, and in some from Northern Europe the state of preservation is so remarkable that, thanks to the monumental works of Stensio and others, we now know a great deal about the structure of the brain, the sense organs, and the cranial nerves and blood vessels of these primitive animals. Even supposed electric organs somewhat similar to those of the modern *Torpedo* have been found in ancient Cephalaspids from the Upper Silurian. A few years ago we knew almost nothing about the jaw structures of the Ostracoderms. They have now been found in all but a few.

Through these new forms we are also coming to a better understanding of the trend that evolution must have taken among them. In some of the oldest vertebrates the head and foretrunk were encased in solid sheets of bony armor. In others equally ancient the same region was defended by numerous stout isolated scales. Until the past few years it was almost universally believed that the extensive shields found in the Ostracoderms arose from a fusion of dentelated scales similar to the placoid scales of the Elasmobranchs. Some doubt has lately arisen in regard to this theory, for we

now know that in the course of evolution among the armored *Heterostraci* there came about a progressive breaking up of the originally extensive carapace into many smaller pieces, and that this subdivision was also accompanied by a more intimate association of the carapace with certain modified scales of the trunk. As time went on these scales became greatly enlarged and were included within the carapace.

The fauna discussed in this paper was found in a limestone lens completely penetrating Beartooth Butte, Wyoming, in such a shape as to strongly suggest an ancient watercourse filled with sediments. In these sediments are found the remains of Ostracoderms and primitive fishes associated with the equally primitive land plants of a *Psilophyton* flora.

The original discovery was made in 1931 by a party of geologists exploring Beartooth Butte in connection with the Princeton Red Lodge Research Project. The fishes were soon after described by the present writer, who considered them to be of Lower Devonian age.[1]

In the summer of 1932 a second expedition to Beartooth Butte led by Dr. Erling Dorf of Princeton University, under the auspices of the William Berryman Scott Research Fund, brought home far larger collections. These contain not only better specimens of those species already described, specimens which throw new light upon their structure, but also a large series of new forms.

As a result of these discoveries it is now clear that I must transfer the forms described in my former paper as Pteraspids to a new family, which I call the *Protaspidæ*. In this family are included at least two genera, with a number of species described herewith.

Among the new forms one of the most interesting is a *Cephalaspis*, the first to be found within the United States. The collections also contain several species belonging in the curious genus *Cardipeltis*. From a study of these I am con-

[1] W. L. Bryant, "Lower Devonian Fishes of Beartooth Butte, Wyoming." *Proc. Amer. Phil. Soc.*, LXXI, No. 5, 1932.

vinced that *Cardipeltis* also should be assigned to a new family, which I name the *Cardipeltidæ*. Among the true fishes the *Acanthaspidæ* are represented by several new species.

Taken together the fauna herein described seems to be most closely related to the Downtonian and Lower Devonian fishes of Spitsbergen. Cephalaspids and Acanthaspids have also been found associated in the Lower Devonian deposits of Eastern Canada.

The fossils discussed in this paper are imbedded in a fine-grained limestone. They are usually strongly crushed from above, but in many specimens the natural vaulting of the shields remains almost undisturbed. Only detached plates and empty carapaces are preserved, the soft parts having decayed before fossilization. In some fossils the actual "bone" is well preserved, in others the exoskeleton has dissolved through leaching and weathering, leaving only natural moulds of the inner or outer surface. These moulds however exhibit very fine structural details when not too badly weathered.

All numbers of specimens in the text refer to the Paleontological Series in the Geological Museum of Princeton University.

Order *Heterostraci*

Family *Protaspidæ* nov. fam.

Until recently the *Heterostraci* had been subdivided into the families *Cœlolepidæ*, *Drepanaspidæ* and *Pteraspidæ*. Some authors also separated one or two other families of doubtful status. The late Professor Johan Kiaer of Oslo for a number of years had been investigating the exceedingly rich collections of undescribed Pteraspidian fishes made by various Norwegian expeditions to Spitsbergen. These studies were unfortunately interrupted by his death. In a posthumous paper, recently published under the able editorship of A. Heintz,[1]

[1] Johan Kiaer, "The Downtonian and Devonian Vertebrates of Spitsbergen, IV, Suborder Cyathaspida," Kong. Dept. for Handel, Sjofart, Industri, Handverk og Fiskeri, Skrifter og Ishavet, Oslo, 1932, No. 52.

Kiaer divides the *Heterostraci* into three suborders, the *Psammosteida*, *Cyathaspida* and *Pteraspida*. According to Kiaer the *Cyathaspida* should be subdivided into two tribes. The *Poraspidei* with completely undivided shields form one tribe, while the *Cyathaspidei* with dorsal shield divided into four portions by distinct limits in the dentine layer form the second tribe. Four or five families with many genera and species are included in each tribe.

The sections of Kiaer's monograph dealing with organization of the proposed sub-orders, *Psammosteida* and *Pteraspida*, remain for the present unpublished. His diagnosis of the *Cyathaspida* is as follows:

1. The orbits are not surrounded by the dorsal shield, but they form semicircular notches in it.

2. The large oblong branchial plate situated between the dorsal and ventral shields is quite detached.

3. The dentine ridges forming the surface of the dermal skeleton are smooth, not crenated as in the Pteraspids.

Whether or not the first two characters are of subordinal value, I cannot believe the third to be so or even of family value, for among the fossils described herewith are some differing widely in the character of the dentine ridges while agreeing in most other diagnostic features, so far as I can determine from the state of their preservation.

The members of the new family which I propose to name the *Protaspidæ* are excluded from the *Cyathaspidæ* by a number of diagnostic features. They were in a more advanced stage of development, but had not yet acquired a number of characters that distinguished the *Pteraspidæ* to which they were somewhat more closely related. The genera of the proposed new family *Protaspidæ* have the following characters in common:

1. The dorsal shield is composed of four unpaired and two paired elements, fused in the adult.

2. The eyes are enclosed within the dorsal shield.

3. The pineal opening is contained within a well-defined pineal plate.

4. The branchial plate is firmly attached to the dorsal shield throughout its length.

5. The exoskeleton is thin but dense, with few large cancellæ.

6. Impressions of branchial or auditory organs are absent from the inner surface of the shield.

The dorsal shield is divided as shown in Text Fig. 1, *A*. In the median line are the rostral, pineal, median dorsal and

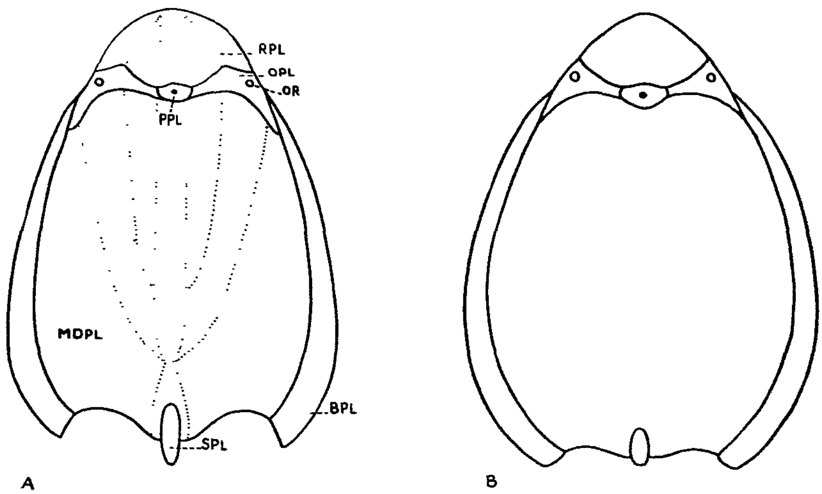

FIG. 1. *A. Protaspis bucheri* Bryant. Plan of the dorsal shield. *BPL*, branchial plate; *MDPL*, median dorsal plate; *OPL*, orbital plate; *OR*, orbit; *PPL*, pineal plate; *RPL*, rostral plate; *SPL*, spinal plate. Sensory canals shown as dotted lines. *B.* Dorsal shield of *Protaspis dorfi* Bryant. In this and all other diagrams, lateral and dorsal plates are represented in the same plane, as if the animal were crushed flat.

spinal plates. The paired lateral plates are the orbitals followed by the long, narrow branchials.

The rostral plate is only slightly inflected beneath. I have never seen any indications of narial notches. The posterior margin of the plate is bounded by the pineal and the paired orbitals. In at least one species the median dorsal also forms part of the posterior boundary. The pineal plate is broader than long. It is usually but not always in contact with the orbitals. In well preserved specimens its boundaries

are always distinctly visible (Pl. XII, Fig. 2; Pl. XVI, Fig. 2).

The angular orbitals are placed dorso-laterally. The dorsal process on these plates reaches nearly or quite to the pineal while a lateral arm extends backwards for a short distance between the median dorsal and branchial plates.

The orbits are always small and directed laterally. They are usually placed slightly in advance of the pineal. Many specimens have been compressed from above in such a way that the dorsal shield has broken at the level of the orbits giving a misleading appearance of semicircular orbital notches as seen, for instance, in the specimen figured on Pl. II, Fig. 1. However, the fragmentary dorsal shield pictured on Pl. II, Fig. 2 clearly shows the orbit wholly enclosed within the orbital plate.

The median dorsal plate is emarginate in front. It usually shows more or less conspicuous lines of growth. At the posterior end it encloses on three sides the median spinal plate which I believe to be a modified scale enclosed within the shield. The line of anchylosis of these plates is apparent in well preserved specimens and is also distinctly shown by an abrupt change in direction of the ornamental striæ. This is illustrated by a fragment of a dorsal shield enclosing the spinal plate, shown on Pl. XXI, Fig. 2.

The branchials are long, curved plates extending from a point about opposite the pineal to the posterior end of the shield. They differ in width in the various species but are always wider behind than in front where they are acutely terminated. These plates occupy a lateral position except at the posterior ends. They are usually firmly anchylosed to the median dorsal plate which they border on either side throughout its entire length except where the orbital plates intervene. There are no branchial openings in the branchial plates and no branchial sinus between branchials and median dorsal.

In two species I have observed a supernumerary plate more or less loosely attached to the postero-lateral angle of

the median dorsal plate and directly behind the posterior termination of the branchial (Plates X, XI).

This plate is triangular in shape, with curved lateral margins and acutely pointed behind. It has every appearance of being one of a pair of cornual plates. It is quite possible that these loose plates occurred in all of the *Protaspidæ*. Should this be the case it is most probable that the branchial openings were situated behind the branchial plates and between them and the "cornual" plates.

Dr. Anatol Heintz of Oslo has called my attention to a Polish Pteraspid-like form, *Podolaspis longirostra*, recently described by W. Zych [1] (Text Fig. 2, *E*). In this form there are several longitudinal rows of fulcra-like scales on the trunk. The median dorsal row immediately follows the median dorsal spine. Two lateral rows follow the cornual plates of the right and left sides and imitate their shape. It is therefore quite possible that the cornual plates in the *Pteraspidæ* and *Protaspidæ* are, like the median spinal plate, modified and enlarged scales incorporated within the dorsal shield. It is to be observed that similar rows of fulcra-like scales also occur in like positions on the trunk of *Cephalaspis murchisoni* Egerton. There seems to have been a cleft between the postero-lateral margin of the ventral shield and the branchial plate, at which point it is barely possible a branchial opening may have occurred.

The ventral shield is always found detached. It is narrower and shorter than the dorsal shield. The plates surrounding the mouth region are unknown.

The sensory canal system is characteristic and fairly uniform throughout the species. When favorably eroded the actual canals may be seen especially on the rostral plate. In natural moulds of the inner surface of the dorsal shield, impressions of the canals caused by a thickening of the bone through which they pass may also be observed. Due to faulty preservation it is seldom that the actual openings of

[1] W. Zych, "Fauna Ryb Dewonu i Dountonu Podola, Pteraspidomorphi: Heterostraci," Lwow, 1931.

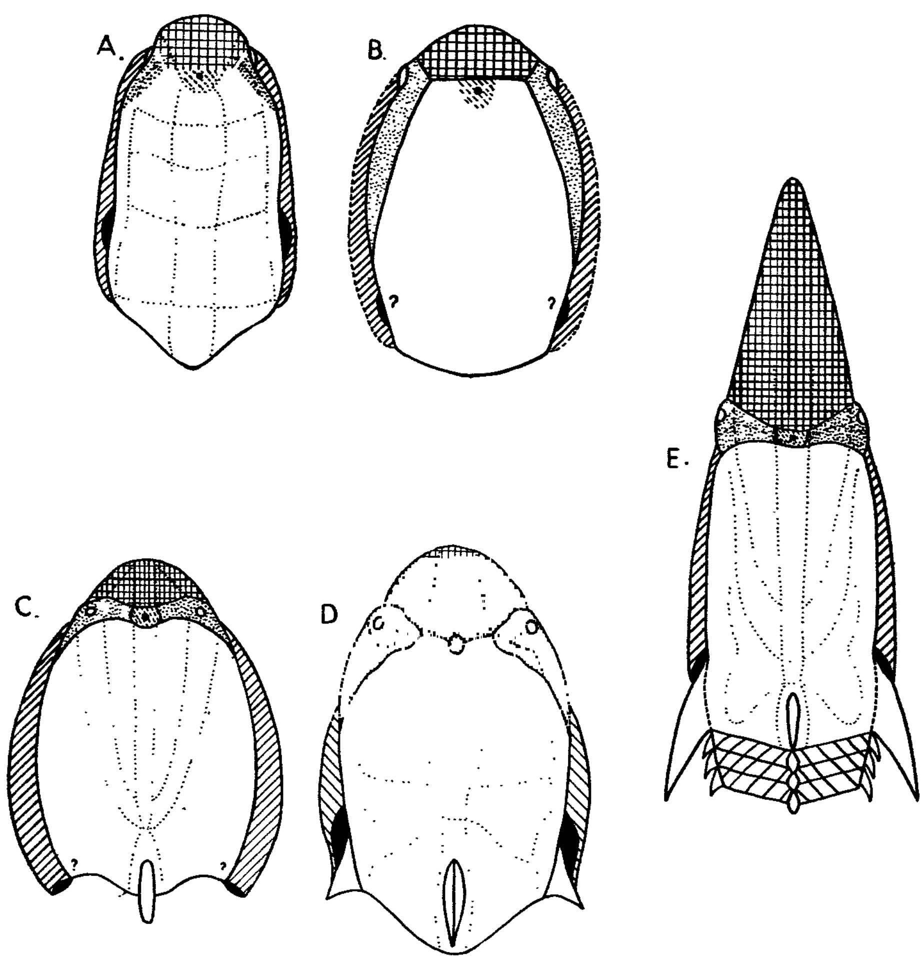

FIG. 2. Stages in the progressive subdivision of the dorsal shield leading from the unbroken carapace of the Silurian Poraspids to the complicated shields of the Devonian Pteraspids. *A*, *Poraspis polaris* Kiaer; *B*, *Cyathaspis banksi* Lank.; *C*, *Protaspis bucheri* Bryant; *D*, *Pteraspis* (?) *primaevus* Kiaer; *E*, *Podolaspis longirostra* Zych. Homologous areas and plates are marked alike. Modified from a sketch in a letter to the author by Anatol Heintz. In the orbito-pineal region *D* is more primitive than *C*. In the possession of well developed cornua and pronounced spine it is more advanced.

the pores leading from the deep-seated canals can be seen. In only one or two fossils have I seen impressions indicating the direction of the sensory canals on the ventral shield.

The posterior part of the body was covered with scales. Only isolated scales are known. Branchial, auditory, nasal, fin and tail structures are unknown.

A tentative restoration of *Protaspis* based upon uncrushed dorsal and ventral shields of *P. dorfi* may be seen on Plate III. The trunk and tail are entirely hypothetical, and the squamation is based only upon detached scales.

The dermal skeleton in the *Protaspidæ* is exceedingly thin. The average thickness is only about one-fifth of a mm. Due to compression it is usually weakened by fine cracks and I have found it difficult to make satisfactory thin sections. The peculiar feature of the exoskeleton is its extraordinary density, and the absence of large cancellæ anywhere in its structure (Pl. IV, Figs. 1, 2).

In the basal layer thin laminæ are laid down parallel to the base. This layer is penetrated by occasional sets of fine canals mutually perpendicular. From all of these issue minute branching tubules. Some of the horizontal canals resemble greatly enlarged cell spaces.

The middle layer consists of very dense tissue also laminated but in this case the thin laminæ are whorled and contorted. Only a very few small cancellæ are to be found in this layer. They are usually elongated and from them also issue a few branching tubules. This layer comprises more than half the substance of the "bone."

The superficial layer of dentine directly succeeds the middle layer. From an elongated pulp cavity beneath each ornamented ridge arise the usual dentine tubules. These fork more and more as they ascend nearly to the surface.

From the foregoing considerations it may be concluded that the *Protaspidæ* belong with none of the families heretofore described, but occupy an intermediate position between the *Cyathaspidæ* and the *Pteraspidæ*.

The new forms discovered in the past few years help to

solve many problems concerning relationship among the oldest vertebrates. We now have a succession of forms leading from the Silurian *Poraspidæ*, with primitive undivided dorsal shield, through such intermediate forms as the *Cyathaspidæ* and *Protaspidæ* to the more specialized Devonian *Pteraspidæ*. The breaking up of the dorsal shield into a number of isolated plates has gradually resulted in the interposition of a series of elements between the rostral and median dorsal plates. We also perceive that the dorsal shield has gradually incorporated within its limits a number of elements originally part of the squamation of the trunk. In *Protaspis* a median spinal plate has become so incorporated, while the branchial plates extend to the hinder limit of the median dorsal plate, rarely having acquired the "cornual" plate so conspicuous in the *Pteraspidæ* but which is probably only a modified lateral fulcrum. Further development may be seen in the arrangement of the sensory canal system (Text Fig. 2).

Genus *Protaspis* nov. gen.

These are relatively large forms in which the dorsal shield is strongly vaulted, the rostral plate short and broad, the branchials narrow. The ventral shield is ovate or tongue-shaped and weakly curved, more so posteriorly. The dermal skeleton is very thin. Its surface is ornamented with fine, subparallel dentine ridges that follow the outlines of the various plates. Nine species of *Protaspis* are known.

Protaspis bucheri Bryant

Pl. I; Pl. II, Figs. 1, 2; Pl. V, Fig. 1; Pl. XXI, Fig. 2; Text Fig. 1.

1932. *Pteraspis bucheri* Bryant. *Proc. Amer. Phil. Soc.*, Vol. LXXI, No. 5, p. 232, Pl. I; Pl. II, Fig. 1; Pl. III, Figs. 1–3; Pl. V, Fig. 2; Text Fig. 1.

New examples of this form collected by the 1932 expedition give us more exact knowledge of the exoskeleton.

It is now clear that the branchial plates extended unbroken along the whole length of the median dorsal except

where separated by the orbitals and that a low spinal plate replaced the dorsal spine found in the *Pteraspidæ*.

The dorsal shield (Text Fig. 1) is only moderately arched, less so than that of *P. dorfi*, and the lateral borders are straighter. The rostral plate is low and quite short, its length contained about five and one-half times in the length of the carapace. In uncrushed specimens the lateral margins of the rostral plate are seen to be sharply deflected. The pineal plate is in contact with the orbitals. These latter are seen to be much shorter than are homologous plates in the *Cyathaspidæ*.

The branchial plates are only gently curved except near the posterior ends where they bend sharply inward. The median dorsal plate is much longer than wide. The spinal plate is a narrow element raised above the surrounding area and projects well behind the median dorsal (Pl. I). After death and during the crushing to which it was subjected the spinal plate in this and other species often became detached and lost.

The superficial ornamentation in this species consists of parallel ridges separated by fine grooves. The sides of the ridges are distinctly crimped. Four or five ridges are contained in 1 mm. (Pl. V, Fig. 1).

Upon nearly all of the dorsal shields and upon their impressions in the matrix occur certain uniform and characteristic markings caused by sensory canals. The sensory canal system in the dorsal shield of *P. bucheri*, so far as it has been observed by the writer, is illustrated in Text Fig. 1.

A pair of median longitudinal canals traverses the length of the dorsal shield. These canals run parallel with and close to the median line, to a point shortly in advance of the spinal plate. Here they approach each other only to diverge and pass on either side of that plate.

Arising from the medial canals in the posterior moiety of the median dorsal plate, two more pairs of canals run obliquely forward and outward. The inner pair probably crosses the orbital plate (although I have not observed it) to join a

pair of canals on the rostral plate. These pass obliquely forward and inward to a point on the front margin of the rostral plate, where they are intersected by the median canals first described. The outermost pair arises shortly in advance of the spinal plate and diverges forwards and outwards across the median dorsal plate to a point near the posterior end of the orbital plate, whence I am unable to trace them.

The pattern of the sensory canal system in *Protaspis* is seen to resemble that in *Podolaspis* (Text Fig. 2), but I have not observed the third and outermost pair of canals found on the median dorsal plate in that form. Nor have I seen the horizontal canals traversing the orbito-pineal region that are found in *Podolaspis* and other *Pteraspids*. It is possible, however, that such canals may eventually be found in *Protaspis*.

The sensory canal system of the ventral shield in *P. bucheri* remains unknown. It probably resembled that in *P. constrictus*, later described (Pl. XIII, Fig. 2).

Protaspis dorfi Bryant

Pl. III; Pl. V, Fig. 2; Pl. VI; Pl. VII; Text Fig. 1, *B*.

1932. *Pteraspis dorfi* Bryant. *Proc. Amer. Phil. Soc.*, Vol. LXXI, No. 5, p. 238, Pl. II, Fig. 2; Pl. IV; Text Fig. 3.

This species attained a greater size than any other member of the family *Protaspidæ*. One ventral shield in the collection (No. 13647) measures 150 mm. in length.

The diagram of the dorsal shield in this species (Text Fig. 1, *B*) would indicate a form more rotund than that of *P. bucheri*. However, it should be understood that in this as in other diagrams the lateral and dorsal plates are shown in the same plane as if the shield were crushed flat. Actually, this animal was deeper bodied than *P. bucheri*. The dorsal shield is steeply vaulted, especially in the rear, and the same is true of the ventral shield but to a lesser degree (Pl. III).

An uncrushed mould of the inner surface of a dorsal shield of *P. dorfi* is shown on Pl. VI. This specimen measures

140 mm. in length. The vaulting attains a height of 28 mm. at a point about 30 mm. from the posterior end, whence it slopes downward in all directions.

The rostral plate was rather narrow and more acutely terminated than that of *P. bucheri.* Its length is contained six and one-half times in the total length of the dorsal shield. The pineal plate is in contact with the orbitals. The spinal plate is short and projects little beyond the rest of the shield. In the type specimen this plate has been broken away, and the true contour of the shield in this region is not shown. The branchial plates are firmly anchylosed to the median dorsal and are quite narrow as in *P. bucheri.*

The dorsal sensory canal system is uniform with that of *P. bucheri*, but the median longitudinal canals are closer to each other.

The ventral shield of *P. dorfi* is wider and more vaulted behind than in front (Pl. VII). The ornamentation found on the plates of this species is extremely fine. The crenated ridges follow in general the outlines of the plates but often become wavy, with intercalated ridges. This ornamentation is illustrated on Pl. V, Fig. 2. Eight of the ridges are contained in one millimeter.

Protaspis brevirostris nov. sp.

Pl. VIII, Figs. 1, 2.

Type: A dorsal shield in yellow limestone (No. 13646).

In this form the dorsal shield is short, broad and deep, tapering rapidly toward the snout (Pl. VIII, Fig. 1). The front margin of the rostral plate is broadly curved. In well preserved specimens the length of the rostral plate is contained five times in the length of the shield. A rather wide pineal plate is in contact with the orbitals.

The median dorsal plate is broad behind, and strongly vaulted. Its greatest width is nearly equal to its length. In every example known to me the posterior end of the shield is somewhat damaged, and its exact contour is uncertain.

The type specimen consists of an uncrushed mould of the

visceral surface of a dorsal shield with considerable areas of bone still adhering. Some of the sensory canals or their impressions are preserved and indicate a canal system similar to that in *P. bucheri*.

A mould of the inner surface of a ventral shield, apparently of this species, is to be seen on Pl. VIII, Fig. 2. It is gently arched in all directions—quite strongly so behind.

The ornamentation in this species consists of grooves alternating with subparallel crenate ridges. Five or six of these ridges are contained in one millimeter.

Protaspis nanus nov. sp.

Pl. IX, Figs. 1, 2.

Type: The front half of a small dorsal shield seen in visceral aspect (No. 13644).

This species is slender and easily distinguished by an unusual characteristic. The pineal plate is not in contact with the orbitals but is separated from them by intervening margins of the median dorsal plate (Pl. IX, Fig. 1).

The rostral plate is long, and its front margin bluntly rounded. Its length could hardly have been contained in the total length of the shield more than three or four times. The pineal plate is oval and well defined, with a large pit, probably not much smaller than the orbits. However, these are not preserved in the type and only specimen showing the head. The median dorsal plate is slender and wider in front than behind. The posterior end is missing, but another specimen (No. 13571) exhibits a truncated posterior margin.

The branchial plates are not preserved in the type specimen, but one may be seen on another specimen (No. 13571). Its shape is similar to those of other Protaspids.

The sensory canal system is well shown in part on the dorsal shield of the type specimen. So far as it can be traced it differs somewhat from the sensory canal system in other Protaspids. A single horizontal canal crosses the median dorsal plate, intersecting the paired longitudinal canals. This canal has not been observed in other species.

The ventral shield is narrowly elliptical in shape with subparallel sides (Pl. IX, Fig. 2). Like the dorsal shield it was gently vaulted. A depressed flange runs across the posterior end of the shield which terminates in a blunt point. The depression in the shield is well shown in specimen No. 13571.

A number of ventral shields of this species are found in the collection. In larger specimens these become proportionately narrower in comparison with the length, showing that most of the growth is in a longitudinal direction. A shield 50 mm. in length is about one and one-half times as long as wide while one 95 mm. in length is twice as long as wide.

The ornamentation on the shields of *P. nanus* consists of crenate ridges. Four of these ridges are contained in 1 mm.

It is probable that when better specimens are forthcoming, it will be found necessary to place this form in a new genus.

Protaspis amplus nov. sp.

Pl. X; Text Fig. 3.

Type: A dorsal shield in yellow limestone (No. 13520).

Many characteristics distinguish this form from other species. The type specimen is strongly crushed from above and the extent to which the dorsal shield was originally vaulted is uncertain. The width of the branchial plates indicates a deep-bodied animal (Pl. X).

The rostral plate is long. It is contained three and one-half times in the total length of the dorsal carapace (Fig. 3). The pineal plate is much wider than long. The median dorsal plate is at least as broad as long. A sharp horizontal depression extends across the plate just in advance of the spinal plate. The latter plate is long and narrow. The branchial plates are broad and comparatively short, extending, however, to the postero-lateral angles of the median dorsal plate.

Cornual plates are apparently present in this species. In the type specimen a more or less detached plate is seen with its proximal end wedged in between the distal extremity of the branchial plate and the right postero-lateral angle of the

median dorsal. This intercalated plate or enlarged scale is clearly differentiated from the adjacent plates by an abrupt change in the direction of the ornamental striæ. I have already discussed the apparent significance of these plates in relation to the scales of the trunk and to the branchial openings.

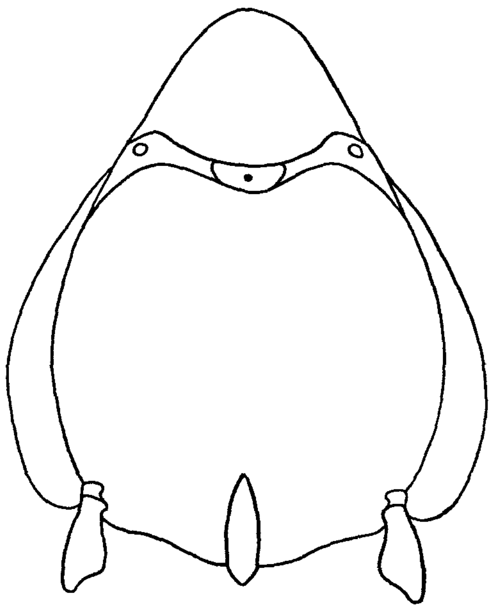

FIG. 3. *Protaspis amplus* nov. sp. Dorsal shield, restored. Based on No 13520.

The superficial ornamentation in this species consists of fine, parallel, crenate ridges separated by very narrow grooves. Five of these ridges are contained in the space of 1 mm.

Most of the exoskeleton in the type specimen has weathered away, but the sensory canal system as indicated by impressions in the matrix is closely similar to that in *P. bucheri*. The ventral shield is unknown.

Protaspis perlatus nov. sp.

Pl. XI; Text Fig. 4.

Type: The left half of a dorsal shield seen from the visceral side and imbedded in yellow limestone (No. 13565).

This species is based upon a single specimen (Pl. XI). Only the left side of the dorsal shield is preserved. Most of the bone, somewhat crushed, still adheres to the matrix. The shield was very wide posteriorly and strongly arched. Its length in the median line is 115 mm. The greatest width is at a point about 40 mm. from the posterior end. At this point the shield must have been considerably wider than long (Text Fig. 4).

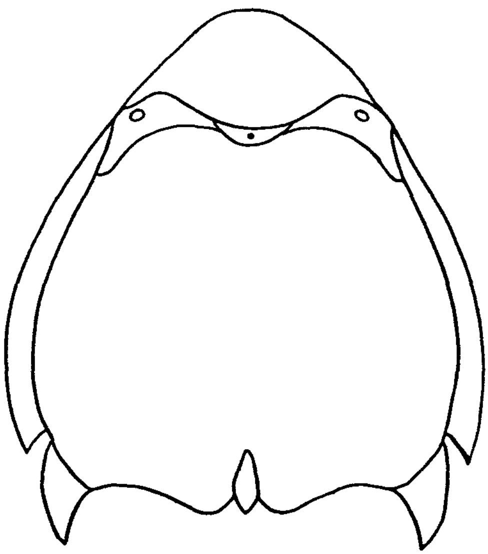

FIG. 4. *Protaspis perlatus* nov. sp. Dorsal shield, restored. Based on No. 13565.

The length of the rostral plate is contained slightly more than four times in the total length of the shield. The pineal plate is small, wider than long and is in contact with the orbitals. The spinal plate is seen only as a deep impression in the matrix showing the ornamentation in clear detail. It is laterally compressed, spine-like and prominent above the surface of the adjacent area. The crest of this plate must have been about as high as long.

What appears to be a "cornual plate" is seen as a clear impression at the postero-lateral angle of the shield. At its junction with the dorsal shield the bone is more or less destroyed and from the impression in the matrix one cannot

be certain that this was indeed a separate plate or only a prolongation of the median dorsal plate. From the direction of the ornamentation it seems probable that the former was true and that this plate is the homolog of that found in *P. amplus*. It will be observed that the distal end of the branchial plate is not in contact with the cornual plate or process, suggesting that the branchial opening may have been located in the gap between the plates.

The ornamentation consists of parallel, crenate ridges and grooves. Five of these ridges occupy the space of 1 mm.

Protaspis perryi nov. sp.

Pl. XII, Figs. 1, 2.

Type: A fragmentary dorsal shield in yellow limestone (No. 13518).

The single specimen upon which this species is based consists of the greater part of a dorsal shield. Unfortunately, both ends of the specimen have broken away and the true contour of the shield can only be estimated. The outer surface of the shield is exposed, with most of the bone adhering (Pl. XII, Fig. 1).

The rostral plate was apparently long and narrow. The outlines of the pineal plate are plainly evident (Pl. XII, Fig. 2). It is in contact with both orbitals and the pineal pit is prominent. The median dorsal plate is wide with comparatively straight sides. Both orbitals and a considerable portion of the right branchial plate are preserved.

A diagnostic feature of this species is found in the superficial ornamentation. The usual subparallel, continuous ridges so characteristic of the foregoing species are, in this form, replaced by ridges which are broken up into short lengths. These vary from somewhat elongated tubercles to ridges of considerable length. They are arranged in subparallel rows, usually following the contours of the various plates, but with many intercalated ridges and tubercles (Pl. XII, Fig. 2). The longer ridges are crenate. One might imagine that certain of the crenations had developed to such

an extent that the ridges were completely bisected. About five ridges are contained in one mm.

The sensory canal system resembles that in *P. bucheri*.

This species is named in honor of Dr. Elwyn Perry of Williams College, who first discovered the Beartooth fish fauna.

Protaspis cingulus nov. sp.

Pl. XIII, Fig. 1.

Type: The mould of a ventral shield in yellow limestone (No. 13563).

The ventral shield in this species resembles that of *P. nanus* in several respects but is much wider in proportion to its length. It is ovate in outline, the greatest width occurring at about the middle of the plate.

The specimen selected as the type (Pl. XIII, Fig. 1) measures 117 mm. in length and 68 mm. in greatest width. It consists of a mould of the visceral surface of a complete shield, with small patches of bone adhering. A sharply depressed flange 10 mm. in length forms the posterior end of the plate.

The ornamentation consists of crenate ridges and grooves. Five of these occupy the space of one mm.

Protaspis constrictus nov. sp.

Pl. XIII, Fig. 2.

Type: A ventral shield in yellow limestone preserved with counterpart (No. 13516).

The type specimen is a ventral shield of large size imbedded in the matrix with the visceral surface exposed (Pl. XIII, Fig. 2). It measures 128 mm. in length and 84 mm. in greatest width. The shield is broadly ovate in outline, but at a distance of about 35 mm. from the posterior end, the shield is constricted, the lateral outlines curving inwards for a short distance.

This is the only ventral shield in which I have found impressions showing the course of the sensory canals. From these impressions it is evident that two pairs of canals arising

far back on the shield ran obliquely forward and outward, terminating on or near the front margin of the shield.

The superficial ornamentation consists of parallel, crenulate ridges and grooves. Four of these are contained in one mm.

Genus *Cyrtaspis* Bryant

This genus was proposed in 1932 to distinguish a pair of overlapping plates with peculiar ornamentation found in counterpart on the same slab, and considered to represent the dorsal and ventral shields of one individual. The specimens were preserved as moulds of the visceral surface.

New and better material collected during the summer of 1932 shows that the specimen described and figured as the ventral shield of *Cyrtaspis ovatus* is in fact the median dorsal plate of that species; that the specimen considered to be the dorsal shield is probably a ventral shield of the same, or a related species; and that the supposed large orbital notches occurring in the latter plate are not such in fact, but are due to faulty preservation of the shield.

In the light of our new material a redefinition of the genus is necessary. This may be stated as follows: Forms closely related to the genus *Protaspis* and differing in the wider branchial plates and in the superficial ornamentation. This consists of continuous linear rows of beads or papillæ arranged to follow the contour of the various plates, thus forming a conspicuous and characteristic ornamentation.

Cyrtaspis ovatus Bryant

Pl. V, Fig. 3; Pl. XIV, Figs. 1, 2; Text Fig. 5.

1932. *Cyrtaspis ovatus* Bryant. *Proc. Amer. Phil. Soc.*, Vol. LXXI, No. 5, p. 242. Pl. VI, Fig. 1; Text Fig. 4. Median dorsal plate only.

A number of more or less fragmentary specimens in the new collections may be referred to this species. Perhaps the best of these is No. 13533 shown on Pl. XIV, Fig. 1. We have here most of the left side of a dorsal shield seen in visceral view with the left branchial plate attached. A restored out-

line of the dorsal shield based on this and other specimens is shown in Text Fig. 5.

The rostral plate is very large, being contained in the total length of the shield only about three times. The orbital plates have very long dorsal processes embracing on each side the small pineal plate. The median dorsal plate is

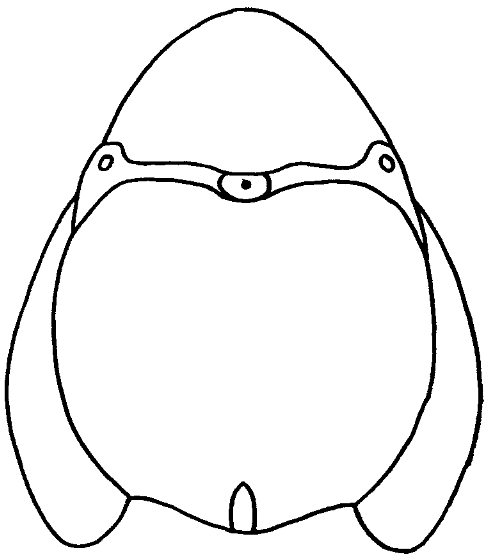

FIG. 5. *Cyrtaspis ovatus* Bryant. Dorsal shield, restored. Based on No. 13533 and other specimens.

broader than long. Its posterior margin is truncated. The spinal plate is short. It was apparently easily detached since it is cleanly broken away from most of the shields in the collection. The branchial plates are wide, indicating a deep bodied animal. A well preserved example of a left branchial plate is to be found in specimen No. 13651 illustrated on Pl. XIV, Fig. 2.

The ornamentation consists of linear rows of beads varying somewhat in size. The pustules are often somewhat elongated and rarely confluent. Four linear rows occupy the space of one mm. An illustration of this ornamentation is to be seen on Pl. V, Fig. 3.

Cyrtaspis papillatus nov. sp.

Pl. XV, Figs. 1, 2.

Type: A mould of the visceral surface of a dorsal shield in yellow limestone (No. 13534).

This is a fairly large form, the dorsal shield attaining a length of 125 mm. The rostral region is wide. A broad area in front is flattened into a shovel-like snout (Pl. XV, Fig. 1). The rostral plate is contained about four times in the length of the dorsal shield. The median dorsal plate is wide in front, tapering behind to an acute point. The branchial plates are very wide. Their club-shaped posterior ends are recurved to embrace in part the hinder margin of the median dorsal plate.

The ventral shield (Pl. XV, Fig. 2) is ovate in outline, truncated in front and acutely terminated behind. It is gently vaulted.

The ornamentation in this species is indistinguishable from that in *Cyrtaspis ovatus*.

Cyrtaspis sculptus nov. sp.

Pl. XVI, Figs. 1, 2.

Type: A dorsal shield, lacking the rostral region, in yellow limestone (No. 13550).

This is a comparatively slender form. The median dorsal plate is somewhat longer than wide, narrower in front than behind, and oblong in shape. The short rostral plate is missing in the type specimen, but in another fragmentary example it is well preserved in connection with the orbital and pineal plates (Pl. XVI, Fig. 2). The latter is a short, wide, triangular element. The orbital plates are in contact with the pineal. The branchial plates are wide. The dorsal carapace was strongly vaulted. The sensory canal system so far as it can be seen is similar to that in *Protaspis*.

A ventral shield in the collection (No. 13561) is referred with some hesitation to this species. It represents an individual larger than the type. It is much longer than wide, with comparatively straight sides.

The beaded ornamentation in this species is indistinguishable from that in other members of the genus.

Cyrtaspis falcatus nov. sp.

Pl. XVII, Fig. 1.

Type: A fragmentary dorsal shield in yellow limestone (No. 13575).

The unique specimen upon which this species is founded consists of a mere fragment of a dorsal shield with parts of both branchial plates attached and seen in visceral view. The pineal plate is preserved but the rostral and orbitals are missing. Most of the median dorsal plate has been lost but its contours may be estimated with some degree of accuracy. It was somewhat broader than long with curving sides. The posterior termination was narrow and probably pointed.

The remarkable feature of this specimen consists in the enormously wide branchial plates. These curve inwards and embrace at least half of the posterior margin of the median dorsal plate.

The ornamentation is closely similar to that of *Cyrtaspis ovatus*.

Family *Cardipeltidæ* nov. fam.

The genus *Cardipeltis* was established by Branson and Mehl in 1931 [1] to distinguish a large cephalic shield and associated tegmen of the trunk, found in the lower member of the Jefferson formation of Blacksmith Fork near Logan, Utah. The microscopic structure of the exoskeleton showed this form to belong with the *Heterostraci*.

Fragmentary shields unquestionably representing this genus were later discovered in the fish lens at Beartooth Butte and were noticed by the writer.[2] The collections made in 1932 by the second expedition contain a number of fine cephalic shields representing two new species of the genus *Cardipeltis*. From a study of these I am convinced that

[1] E. B. Branson and M. G. Mehl, "Fishes of the Jefferson Formation of Utah," *Journal of Geology*, Vol. XXXIX, No. 6, 1931.

[2] William L. Bryant, "Lower Devonian Fishes of Beartooth Butte, Wyoming," *Proc. Amer. Phil. Soc.*, Vol. LXXI, No. 5, 1932, p. 240.

Cardipeltis is sufficiently removed from all known forms to require a new family for its reception. The characters upon which this family is founded are as follows:

1. The exoskeleton is thin and contains no impressions of pineal, nasal, branchial or other organs except the eyes.
2. The cephalic shield consists of one piece, apparently originating from a single centre of growth.
3. The orbits are large and placed far back in deep lateral notches in the dorsal shield.
4. The superficial sculpture consists of numerous short, round-crested ridges. These do not follow the contours of the shield as in the *Pteraspidæ* and *Protaspidæ*, but radiate in all directions from a point in the median line of the shield, behind the level of the eyes, apparently the focus of growth. However, for the sake of consistency, in view of the remarks on page 288 regarding the great difference in superficial sculpture noted in the Protaspidæ, this heading should, perhaps, be omitted from the definition of the family.

The family *Cardipeltidæ*, while retaining many primitive features, had undergone a reduction in the basal part of the exoskeleton so that, in the cephalic region, it no longer received impressions of internal organs. This degeneration of the carapace reached an advanced stage in the *Cardipeltidæ*, unaccompanied by a sub-division of the dorsal shield.

Genus *Cardipeltis* Branson and Mehl

The type and only genus of the family is exclusively American. The generic characters as given by the authors are as follows: "Dorsal armor consisting of one subcardiform or triangular plate of large size, with length and width about equal and orbital notches near midlength. The dorsal surface is marked by fine, closely crowded vermiform ridges. Ventral shield unknown."

Cardipeltis sinclairi nov. sp.

Pl. XVIII, fig. 1; Text Fig. 6.

1932. *Cardipeltis wallacii.* W. L. Bryant. *Proc. Amer. Phil. Soc.*, Vol. LXXI, No. 5, p. 240, Pl. V, Fig. 1.

Type: A dorsal shield in counterpart in grey limestone (No. 13515).

The specimen selected as the type of this species is a fine, large dorsal shield preserved in counterpart and exhibiting the dorsal aspect (Pl. XVIII). The shield has a length in the median line of 163 mm. and an extreme width of 180 mm. The greatest width in the rostral region is 135 mm. The distance from a point in the median line opposite the eye notches to the tip of the snout is 80 mm.—about half the length of the shield (Text Fig. 6).

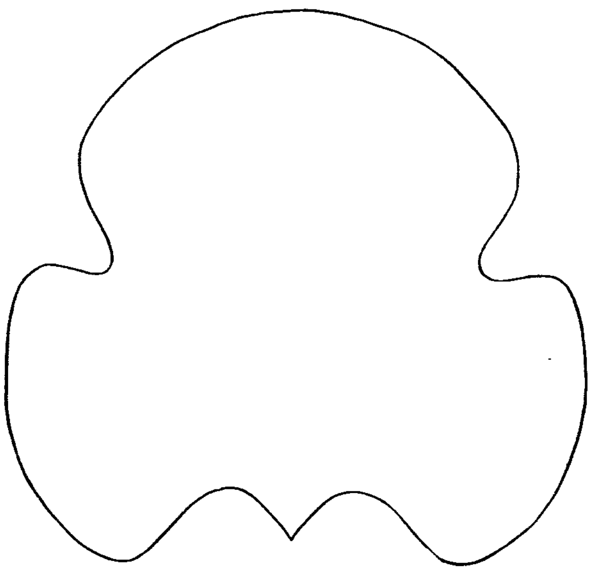

FIG. 6. *Cardipeltis sinclairi* nov. sp. Outline of dorsal shield, based on No. 13515.

The shield is strongly arched from front to rear and from side to side. The greatest vaulting is at a point midway between the orbits. The exoskeleton is very thin but at the posterior end in the median line it is somewhat thickened to form a slight keel.

The eye notches are very deep. A very curious feature of these notches consists in a deep furrow in the bone behind each notch. These excavations are directed obliquely back-

ward and inward as though to allow greater range for the orbits in looking upwards. In front of the orbital notches the rostral region is greatly expanded laterally.

The shield is broadly rounded in front and deeply emarginate behind with a median projection. The superficial ornamentation consists of radiating vermicular ridges. These average about 1 mm. in width and 5–10 mm. in length. Near the margin of the shield they are shorter and round or polygonal in shape.

I have seen no indications of narial notches in any specimen.

This species differs from *Cardipeltis wallacii* Branson and Mehl in the deeper orbital notches, in the much wider rostral region and in general proportions.

I take pleasure in naming this species in honor of Dr. William J. Sinclair, Professor of Geology in Princeton University.

Cardipeltis oblongus nov. sp.

Pl. XIX; Text Fig. 7.

Type: A dorsal shield in grey limestone (No. 13514).

This is a much narrower form than *C. sinclairi*, and not so emarginate in the posterior border. The type specimen (Pl. XIX) measures 167 mm. in length and 152 mm. in greatest width. The greatest width in the rostral region is 119 mm. The distance from the snout to a median point opposite the orbits is 77 mm.

The shield is strongly vaulted and as in the foregoing species the highest point is midway between the orbits. From here the shield slopes downward in all directions. Behind the orbits the posterolateral margins are sharply deflected. The posterior margin is not well preserved. Evidently it was far less emarginate than in other species (Text Fig. 7).

At the orbital notches the margins of the shield are deeply infolded. The anterior margin of the rostral area is imperfect, but there are no indications of narial impressions. Neither in this nor in any other species have I seen any positive evidence of the nature of the sensory canal system.

The superficial sculpture in this form consists of radiating vermicular ridges, indistinguishable in form and arrangement from those in other species.

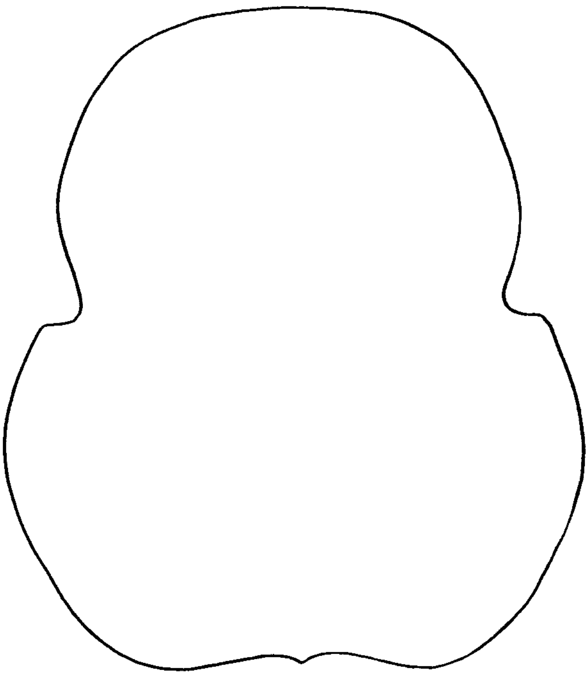

FIG. 7. *Cardipeltis oblongus* nov. sp. Outline of dorsal shield, based on No. 13514.

FORMS OF DOUBTFUL POSITION

Several fragments of plates in the collection differ from all others heretofore described and probably represent new genera. I illustrate two of these forms hoping to stimulate the search for better specimens. On Pl. XXI, Fig. 1 there is to be seen a photograph showing the middle layer of a fragmentary dermal plate (specimen No. 13648). This fragment exhibits a beautiful impression of what is evidently a portion of the sensory canal system of some remarkable Pteraspid-like form. The superficial sculpture of the plate is not preserved. I know of no form with which to compare this specimen.

On Pl. XVII, Fig. 2 I illustrate a fragment of a shield ornamented with a sculpture differing from that in any of the described forms (No. 13654). This ornamentation consists of smooth, flat-crested, meandering ridges separated by fine grooves. The ridges vary in length as well as in width, are often intercalated, and are sometimes arranged in whorls like finger prints. Elsewhere, they run in a fore and aft direction. About four ridges are contained in 1 mm. In some respects this ornamentation recalls that in *Eoarchegonaspis* (*Cyathaspis*) *wardelli* Bryant, from the Silurian of Pennsylvania, but the exoskeleton represents a far larger animal.

Order *Osteostraci*

Family *Cephalaspidæ*

Cephalaspis wyomingensis nov. sp.

Pl. XVIII, Fig. 2; Pl. XX, Figs. 1, 2; Text Fig. 8.

Type: A large fragment of a cephalic shield seen in dorsal aspect (No. 13479). Supplementing the type is another specimen exhibiting the cornual region (No. 13576).

The expedition to Beartooth Butte in 1932 secured a number of more or less fragmentary and abraded specimens, important nevertheless, since they constitute the first positive evidence of the occurrence of Cephalaspids within the boundaries of the United States.

The type specimen, Pl. XX, Fig. 1, consists of a large portion of the cephalic shield including the rostral and orbital regions, while a supplementary specimen, Pl. XX, Fig. 2, exhibits the right margin of a shield so far as preserved, including the cornual region. From these it is possible to estimate the contour of the shield, except in the posterior median zone, with approximate accuracy (Text Fig. 8).

The greatest width of the shield is 120 mm. It is widest in the orbital region. The length from tip of the rostral to a line connecting the posterior ends of the cornua is approximately 148 mm. The shield is therefore that of a comparatively large animal. The exoskeleton was very thin and apparently somewhat flexible, for in its fossil state the type

specimen is seen to have been more or less crushed and dented without developing breaks or fissures.

The forward end of the shield is imperfect but it evidently terminated in an obtuse rostral angle. The orbits are circular and placed far apart. They are surrounded by a thin layer of bone. This layer is elevated from the surrounding area and has the appearance of a sclerotic ring. It has an orna-

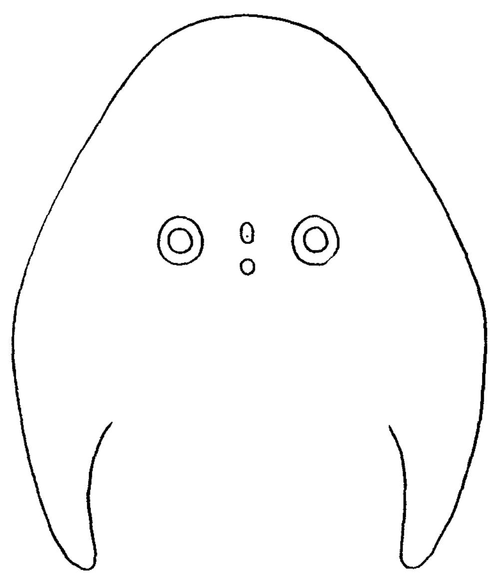

FIG. 8. *Cephalaspis wyomingensis* nov. sp. Restored outline of cephalic shield. Based on Nos. 13479 and 13576.

mentation of fine granulations, but is probably perichondral bone. The orbits are directed more upwards than laterally.

Midway between the orbits lies a small fossa, called the fossa circumnasalis. From this arises a longitudinal prominence perforated by two minute openings. Whether these are connected by a slit is uncertain. On good evidence the anterior opening is considered to be the opening for the hypophiseal sac. The posterior opening is the unpaired nasal aperature (Pl. XVIII, Fig. 2).

Just back of the orbits, in the mesial line, and directly

behind the naso-pituitary openings, is the large pineal prominence. It is broadly ovate and its crest is apparently pierced by a rather wide opening. It is remarkable that the pineal and nasal openings should be located so far back in relation to the orbits.

The cornua were wide and directed inwards, indicating a slender trunk. The example at hand is much compressed, probably the result of crushing.

The integument of the shield is divided into small, polygonal areas by a system of interareal grooves. As the superficial surface of the bone is abraded in every specimen, the ornamentation remains unknown.

Curiously enough there are no indications on the type specimens of the usual impressions of paired and median electric fields to be seen on nearly all Cephalaspid shields, and no doubt correctly interpreted by Stensio as electric fields. Neither is there any indications that such fields were covered over by scales differing in size and arrangement from those on other parts of the shield. I believe that these fields were originally present and that they are not apparent because of faulty preservation. A small fragment of another shield (No. 13653) shows what certainly appears to be a well defined portion of a lateral electric field.

PRINCETON UNIVERSITY, PRINCETON, NEW JERSEY,
THE WILLIAM BERRYMAN SCOTT RESEARCH FUND.

PLATE I

Protaspis buckeri Bryant. Crushed, but nearly complete dorsal shield. The specimen is preserved in counterpart. (No 13517) × 1.

PLATE II

1

2

FIG. 1 *Protaspis bucheri* Bryant. Impression of rostro-orbital region. Due to faulty preservation the orbit appears as a notch in the dorsal shield. (No. 13519.) × 2.

FIG. 2 *Protaspis bucheri* Bryant. Fragment of a dorsal shield showing the orbit enclosed within the orbital plate. (No. 15477.) × 1.

PLATE III

Protaspis dorfi Bryant. Restoration of fish. Trunk and tail are hypothetical. The squamation is merely based upon detached scales.

PLATE IV

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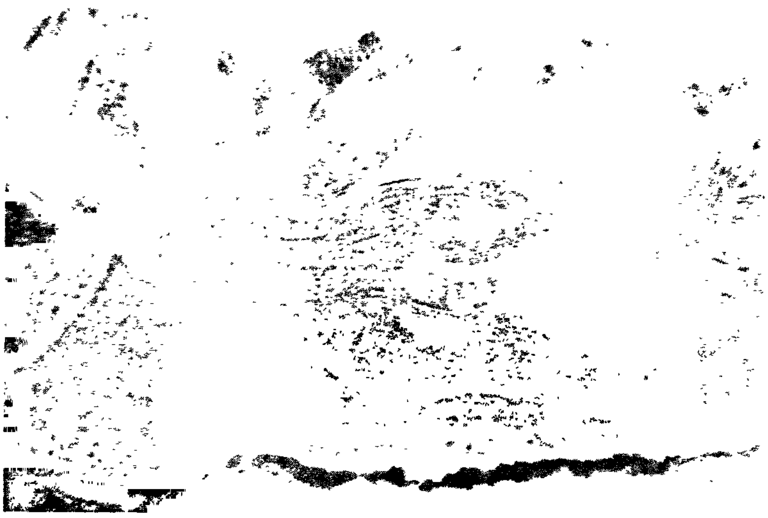

FIGS. 1, 2 Cross sections showing the minute structure in Protaspid shields, greatly enlarged *Cyrtaspis* sp.

PLATE V

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3

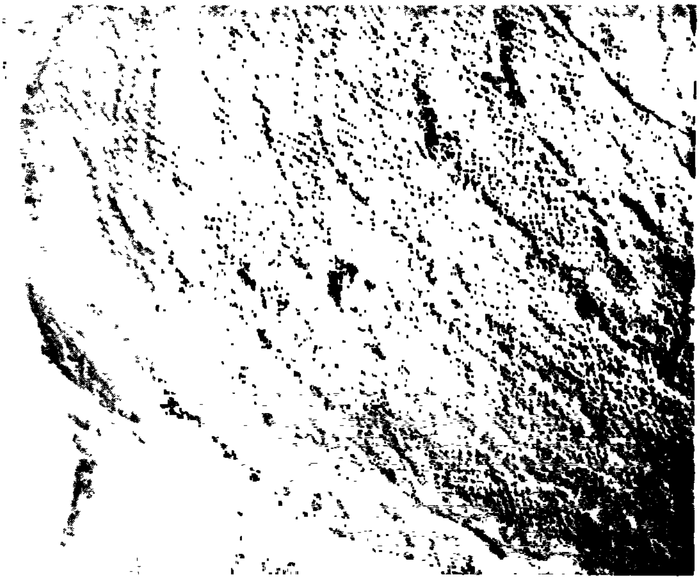


FIG. 1. *Protaspis [illegible]* Bryant. Details of superficial ornamentation × 2

FIG. 2 *Protaspis dorfi* Bryant Details of ornamentation × 2. (No. 15536)

FIG. 3 *Cyrtaspis [illegible]* Bryant. Details of ornamentation. × 2.

PLATE VI

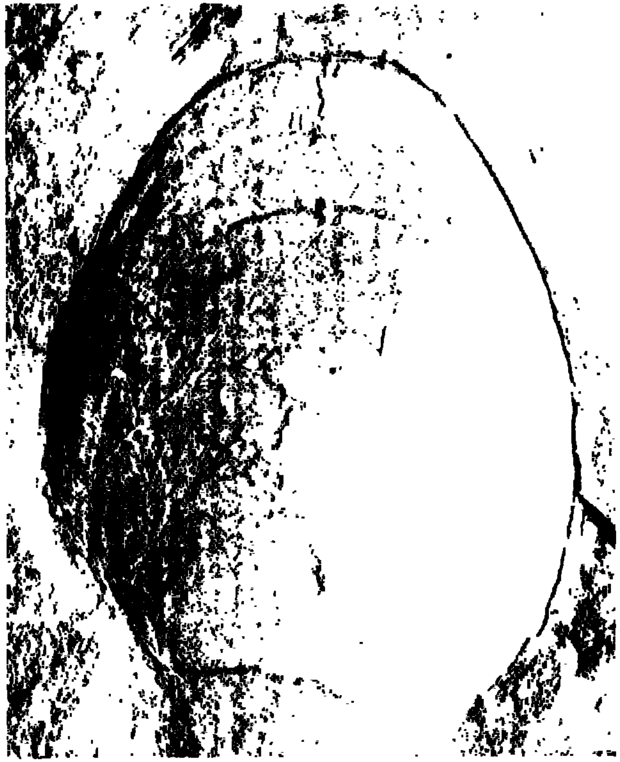
Protaspis dorfi Bryant. Visceral mould of uncrushed dorsal shield.
(N. 13649) × 4/5.

PLATE VII

Proraspis wongi Bryant. Uncrushed ventral shield. (No. 13541) × 1

PLATE VIII

1



2

FIG. 1. *Protaspis brevirostris* nov. sp. Type. Dorsal shield. (No. 13646.) × 1.
FIG. 2. *Protaspis brevirostris* nov. sp. Visceral mould of ventral shield. (No. 13643.) × 1.

PLATE IX

1

2

FIG. 1. *Protaspis nanus* nov. sp. Type. Fragmentary dorsal shield showing sensory canals. (No. 13644.) × 1.
FIG. 2. *Protaspis nanus* nov. sp. Visceral mould of ventral shield. (No. 13572.) × 1.

PLATE X

Protaspis ampla nov. sp. Type. Dorsal shield (No. 13522) × 1

PLATE XI

Protaspis perlata, nov. sp. Type. Incomplete dorsal shield in visceral aspect. The spinal plate is shown but most of the right side of the shield is missing. (No. 13565.) × 1

PLATE XII

1

2

Fig. 1. *Protaspis perryi* nov. sp. Type. Fragmentary dorsal shield. (No. 13518.) × 1.
Fig. 2. *Protaspis perryi* nov. sp. Pineal region of type specimen showing details of sculpture. × 2.

PLATE XIII

1

2

FIG. 1. *Protaspis cingulus* nov. sp. Type. Visceral mould of ventral shield (No. 13563.) × 1.
FIG. 2. *Protaspis constrictus* nov. sp. Type. Ventral shield showing traces of sensory canals. (No. 13516.) × 4/5.

PLATE XIV

1

2

FIG. 1. *Cyrtaspis ovatus* Bryant. Fragmentary dorsal shield in visceral view. (No. 13533.) × 1.

FIG. 2. *Cyrtaspis ovatus* Bryant. Left side of median dorsal plate with wide branchial plate attached. (No. 13651.) × 1.

PLATE XV

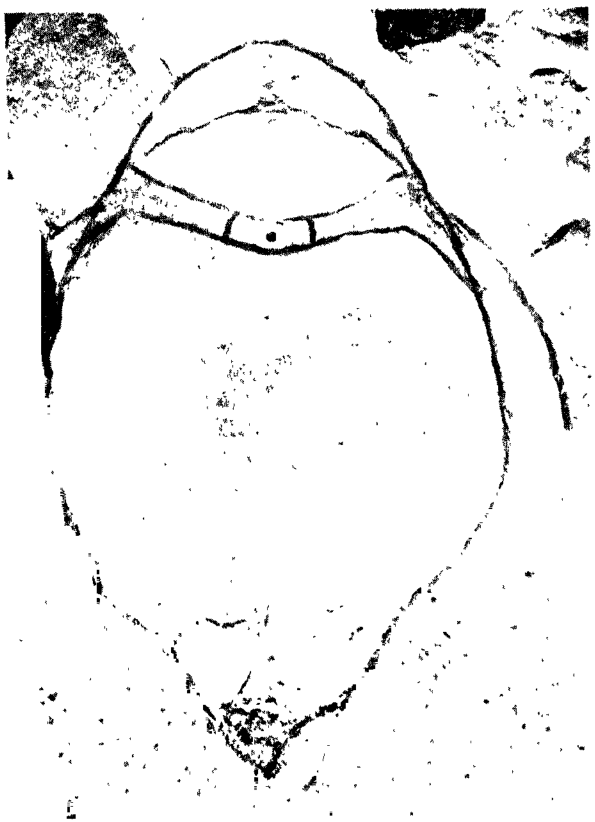


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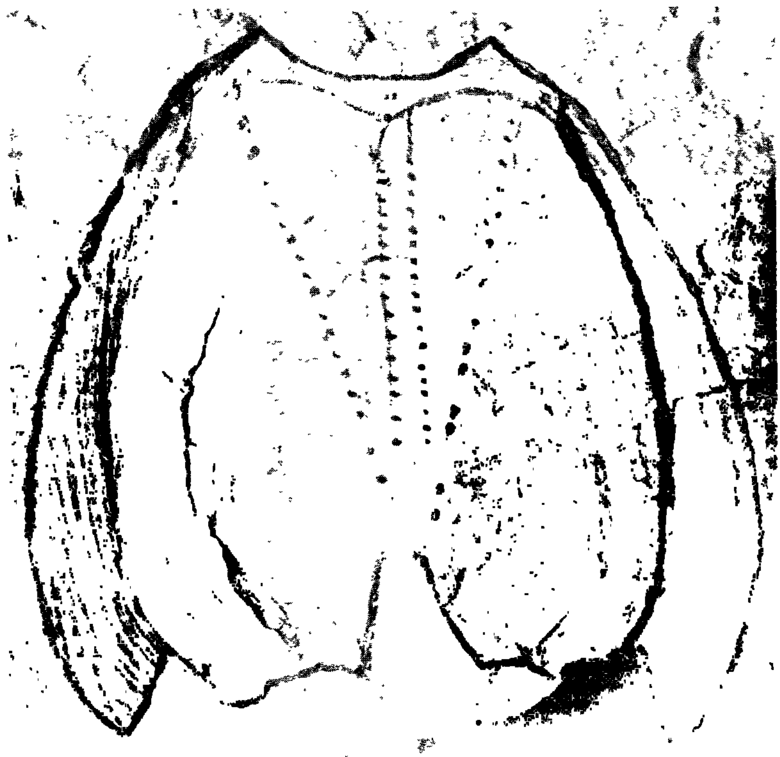
FIG. 1. *Cyrtaspis papillatus* nov. sp. Type. Mould of the visceral surface of a dorsal shield. (No. 13534.) × 4/5.
FIG. 2. *Cyrtaspis papillatus* nov. sp. Complete ventral shield. (No. 13542.) × 1.

PLATE XVI

1



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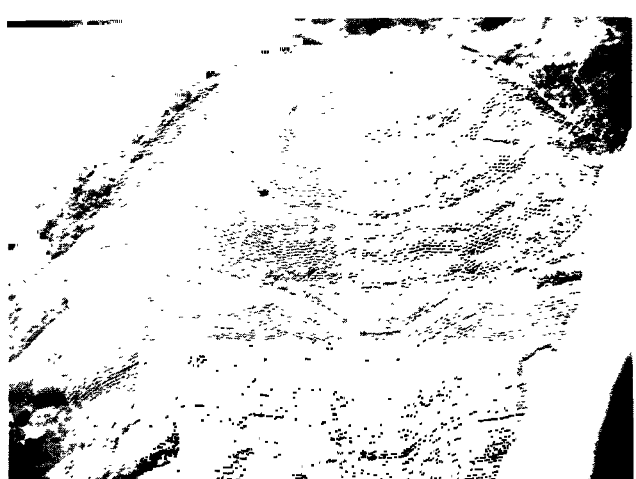

FIG. 1. *Cyrtaspis [illegible]lptus* nov. sp. Type. Dorsal shield lacking the rostral region. (No. 13552.) × 1.

FIG. 2. *Cyrtaspis [illegible]lptus* nov. sp. Enlarged view of rostro-pineal region. (No. 13531.) × 1½.

PLATE XVII

1

2

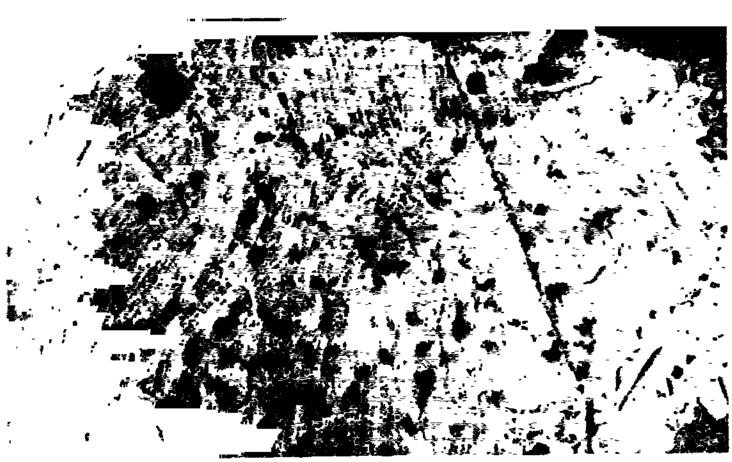

FIG. 1. *[illegible]* nov. sp. Type. Fragment of dorsal shield showing extremely wide branchial plates. No. 13575. × 1.

FIG. 2. Genus and sp. indet. Fragmentary plate showing peculiar ornamentation. (No. 13654.) × 3.

PLATE XVIII

1

2

FIG. 1. *Cardipeltis striolata* nov. sp. Type. Uncrushed dorsal shield preserved in counterpart and showing the deep orbital notches. (No. 13515.) × about ½.

FIG. 2. *Cephalaspis wyomingensis* nov. sp. Type. Enlarged view of pineal region showing as well the fossa circumnasalis from which arises a prominence with two openings. (No. 13479.) × 2.

PLATE XIX

Cardipeltis oblongus nov. sp. Type. Uncrushed dorsal shield. (No. 13514.) × 4/5.

PLATE XX

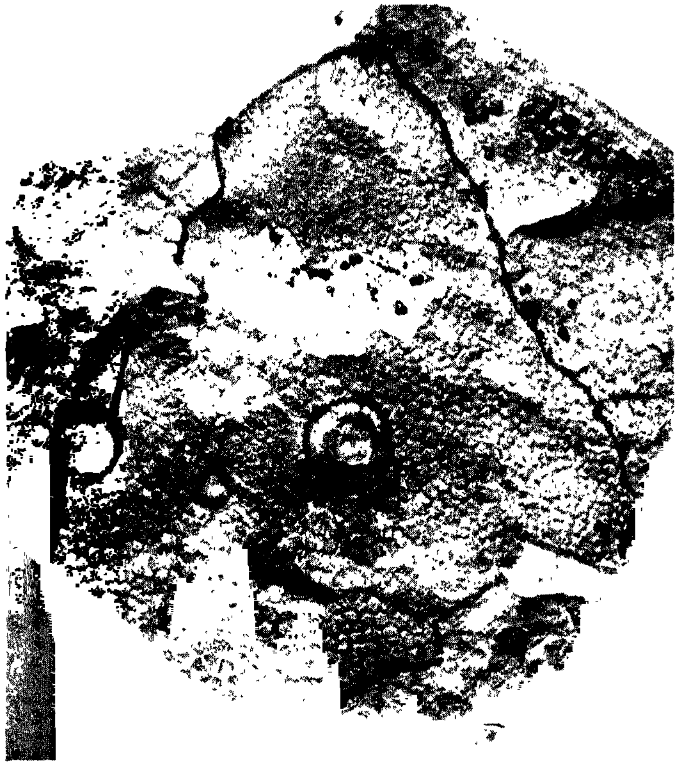

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FIG. 1. *Cephalaspis wyomingensis* nov. sp Type. Fragment of cephalic shield showing the orbito-pineal region. (No. 13479.) × 1.

FIG. 2. *Cephalaspis wyomingensis* nov sp. Cotype. Right margin of a cephalic shield showing the cornual region. (No. 13576.) × 1.

PLATE XXI

1

2

FIG. 1 Gen. and sp. indet. Fragmentary shield showing a peculiar sensory canal system (No. 13648.) × 2.

FIG. 2 *Protaspis bucheri* Bryant. Impression of spinal plate showing ornamental striae running at right angles to those of the median dorsal plate (No. 13573.) × 2.

THE FOREHEAD

ALEŠ HRDLIČKA

(Read April 21, 1933)

One of the chief features of man in æsthetics, in the popular mind and popular literature, in art, and in the mistaken old doctrines of the "phrenologists" and "physiognomists," the forehead has received unexplainably little attention in science, save as to an occasional descriptive characterization.

In anthropometry, outside of my own work, the only measurements taken on the forehead, and they but occasionally, were those of the minimum frontal diameter, and those relating to frontal bulging or slope. The sloping forehead, regarded generally as a sign of inferiority, received especial attention, though mostly only descriptively. The most important dimension of the forehead, its height, was almost totally neglected. The only data on its measurement are those of the artists and are embodied in a few of the artists' "canons."

The oldest of these canons or artists' standards in which the height of forehead is dealt with is that of Jean Cousin and dates from the latter half of the XVI century.[1] In this the height of the forehead, between the *eyebrows* and the *hair line*, is given as equal to the length of the nose, which equalled 1/32 of the stature. This canon, modified somewhat by Blanc, became the lasting standard of French artists.[2] In its eventual form it stipulated that the forehead, from *hair line* to the *root of the nose*, was equal to 1 nose length, which in turn equalled 1/30, or 3.33 per cent, of the stature.

The reasons why workers in anthropology failed to measure the height of the forehead, was the uncertainty of the landmarks. Whether one should choose the line of the eyebrows

[1] *Livre de portraiture.* Paris, 1571.

[2] P. Topinard, *Eléments d'Anthropologie gén.*, Paris, 1885.

or the root of the nose for the lower limit, the point was more or less indefinite, and the same appeared to be true of the upper limit, which was considerably affected by the variation in hair insertion, and in whites by the early loss of hair in that region in many male individuals.

My own interest in the measurement began almost with the commencement of my anthropometric work, in the middle nineties of the last century. Feeling the value of this determination I endeavored so to regulate the landmarks that they could always be followed with the least possible difficulty. The precision of the upper landmark was fairly easy. It was seen that in the majority of people the hair line over the forehead formed a fair arch on which it was easy to mark the point needed and which corresponded to the meeting of this arch and the central vertical line of the front. In numerous individuals, however, particularly males, the hair in the median line extends more or less downward in the form of an angle; where this exists it is disregarded, the hair arch being completed above it and the median point marked on it as usual. As to the lower landmark, I tried simultaneously both the inter-brow point and the nasion, which led to the final adoption of the nasion. Here a considerable uncertainty was met with and had to be overcome. There are many living of both sexes in whom the nasion can be detected certainly neither by sight nor by touch. The only way to determine its location with sufficient accuracy was found to be a thorough acquaintance with it in skulls, and through extended direct comparison of the skulls with the living. In that manner alone can proficiency be gained and a generally reliable measurement be assured. Even then there will doubtless be occasional errors, but these will not be large and will tend to compensate each other in the larger series.

It was on this basis that measurements of the height of the forehead have been carried on in all my anthropometric work since 1898. The procedure was and is to determine carefully and mark the hairline point as well as the nasion, and then to measure with the head calipers from the lowest point of the chin

the two heights of the face (menton-nasion, menton-crinion); the difference between these gives the height of the forehead. When the observer is well experienced, after years of effort, he may do away with the marking, but this is safer and to those with less experience indispensable. Under such conditions the results of the measurements on adequate series of subjects are quite reliable.

My accumulated data on height of forehead extend now to many groups of the Indians, to some Egyptians,[1] to old American and a number of groups of the Old World whites,[2] some negroes,[3] and the Alaskan Eskimo.[4] The most recent series of whites is a highly interesting and representative group of prominent brain workers, members of the National Academy of Sciences. The subject is thus so advanced that it justifies a summing up and a presentation of the results.

The data at hand are to be considered in relation to three chief problems. The first of these is that of the correlation of the height of forehead with intellectuality; the second is that of racial differences; and the third that of differences in the two sexes.

Forehead and Intellectuality

Thanks to the measurements taken recently on the members of the National Academy, men who unquestionably represent the intellectual leaders in their lines, it is now possible to get some fairly definite light on the mooted question of the relation of the height of the forehead to brain superiority.

There are four excellent groups for comparison. The first is the standard group of Old Americans,[5] comprising normal men in all walks of life. The second is that of the old American highlanders of northeastern Tennessee—one of the most belated groups educationally and otherwise in this country.

[1] "The Natives of Kharga Oasis, Egypt," Smiths. Misc. Coll., LIX, 1912.

[2] *The Old Americans.* Baltimore, 1925.

[3] "The Fullblood American Negro," *Am. J. Phys. Anthrop.*, 1928, XII, 15–33.

[4] Unpublished.

[5] At least three generations American-born on both sides of the family.

The third group comprises old American members of the National Academy, and the fourth takes in members of the Academy regardless of derivation.[1]

The data on these four groups follow:

HEIGHT OF FOREHEAD

Males

		cm.
510	Old Americans at large	6.59
118	Old Americans: Tennessee Highlands	6.57
25	Old Americans, Members of the National Academy	6.57
32	Members National Academy, irrespective of Nationality	6.58

If the height of the forehead is any index whatever of brain activity and grade, some material difference should certainly appear in the dimension between the mountaineers and the members of the Academy; but there is no such difference. Instead the two groups, so far apart in mental differentiation, have forehead of the identical mean height. And this is true of all the four groups under consideration. The agreement is in fact most astonishing and beyond normal expectation with a measurement of such a nature. Yet it is no accident, for the proportions hold steady when tested on fair subdivisions of the groups.

There are few if any occasions when Anthropology could dispose of data of such a very desirable nature. Groups were studied of much the same derivation, much the same mean stature, but from the extremes of mental training, work and achievement, and to a large extent also from the extremes of environment and habits. Yet no difference in the height of the forehead is found—nor, it may be said at once, in any of its other essential characters. This permits but one possible conclusion, which is that the lowness or height of the forehead, in normal human beings, does not express or have any relation to the kind of brain it helps to harbor. This will be further confirmed in what follows.

[1] As many of the members of the Academy are advanced in years the numbers of those in whom no hair had been lost over the forehead is not large. There were 118, actually, in whom the height of the forehead could not be secured for this reason.

Forehead and Race

Equally remarkable and unexpected conditions as those shown in the preceding section, appear from the study of the forehead height in different races. The next table shows the dimensions in four important human groups.

Height of Forehead

Males

		cm.	Relation to stature (S = 1000)
510	Old Americans at large	6.59	37.8
1,239	American Indians	6.62	39.7
19	Fullblood young to middle-aged American Negroes	6.98	41.4
181	Alaskan Eskimos (Kuskokwim region)	7.16	44.2

All the measurements in the above series were made by myself, by the same method and with one and the same set of accurate instruments. Should there be any bias it would affect similarly all the groups, for their measurements interdigitated in time; but the procedure is based too rationally to permit of much bias in any direction. If the facts are contrary to the anticipation they are none the less realities. They do away completely with the idea that high forehead, in general, indicates a high intellectuality, or that it is a mark of racial superiority.

In both the absolute height of the forehead and its relative value to stature, the white old Americans at large—certainly one of the best of stocks in every way—stand not at or even near the head but at the foot of the four groups. They are surpassed in height of forehead by the Indian, still more so by the negro, and most by the Eskimo. In the absolute measurements the differences in males in favor of the Indian are only one half of a percent, but in favor of the negro they amount to near 6, in favor of the Eskimo near 9 percent; and the last column of the table shows that these differences are even more marked in the relative height of the forehead to stature.

It is regrettable that there are no comparable data on the

Asiatic yellow-browns, on the negrillo and negrito, and on the Australian.

Height of Forehead in Different Branches of the White People

Thanks to the measurements taken since 1910 under my direction by medical members of the U. S. Health Service at Ellis Island, there are now available data on 14 nationalities of male white immigrants. These data include the height of the forehead, and the means of these, on the whole, are remarkably uniform, as well as closely related to those obtained by myself on the Old Americans; yet there are also interesting differences. The absolute measurement, and its per mille relation to stature, follow.

Height of Forehead in Old Americans and in Immigrants

Absolute Measurements	cm.	Height of forehead relatively to stature (S = 1000)	
(25) Armenians	6.0	Armenians	35.9
(50) Hungarians	6.3	English	37.3
(64) French	6.35	Russians	37.4
(50) Russians	6.35	French	37.4
(10) English	6.35	Old Americans	37.8
(50) Greeks	6.4	Greeks	37.9
(50) Rumanians	6.5	Croatians	37.9
(50) Croatians	6.5	Hungarians	38.0
(50) Poles	6.5	Poles	38.2
(50) Northern Italians	6.5	Germans	38.3
(50) Russian Jews	6.55	Northern Italians	38.4
(50) Southern Italians	6.55	Rumanians	38.5
(63) Germans	6.55	Irish	39.3
(510) Old Americans	6.6	Russian Jews	39.7
(32) Irish	6.7	Southern Italians	40.1

The lowest forehead, and that both absolutely as well as relatively to stature, is shown by our group of Armenians, and the differences are large enough to be significant. The Armenian unit possesses also the smallest head of the 14 immigrant groups,[1] but their forehead is low even in relation to the smaller head. This may be an accidental showing.

[1] See my *Old Americans*, 235.

The Armenians are renowned as the shrewdest tradesmen of the Near East. If their forehead is low it must be, it would seem, of the nature of a localized racial character.

The next poorest showing is that of the Hungarians but this is rather close to that of other white groups.

At the top of the series of forehead heights stand in absolute measurement the Irish and the Old Americans, relatively to stature the short Russian Jews and the Southern Italians. There is a suggestion in this that the present lowered stature of these two groups is a secondary acquisition; the slight old negro admixture in both the Southern Italians and the Jews could hardly alone account for the conditions. In the Old Americans, due to their high stature, the height of forehead-stature relation is below the general medium. The position of the Irish, of whom only 32 had been measured, may be somewhat accidental.

While the data on these immigrant series can not be regarded as perfectly representative of the different nationalities, due to the limited numbers of subjects, with the wholly accidental selection of these and hence perhaps biased composition, nevertheless it is plain that barring one real and a few possible exceptions, the groups reflect a substantial racial similarity.

Height of Forehead in the Two Sexes

The height of the forehead, it was seen above, presents unexpected and interesting similarities as well as differences both socially and racially; the data to follow demonstrate that it also shows interesting conditions in the two sexes:

Relation of Absolute Height of Forehead of Females to that of Males
(Males = 100)

Females vs. Males:

Old Americans	*97.9%*
American Indians	*92.3%*
American Negroes	*99.1%*

Relatively to stature:

	Males %	Females %	Females: Males (M = 100)
Old Americans	37.8	38.0	*100.5*
Indians	39.7	39.5	*99.5*
Negroes	41.4	43.8	*105.8*

The main result which appears from these figures is that the relation of the height of the forehead in the two sexes shows distinct differences in the three main American races. There are not many features of the human body that could show such irregularities.

The forehead of the white woman may be taken as a standard. Its absolute height is 2.1 per cent lower than that of the male, but when compared to the stature (and also the size of the head—see my "Old Americans") it actually makes a better showing than that of the male.

The forehead of the Indian woman absolutely, as well as relatively to stature (and size of the head) is decidedly lower than that of the white woman. This lowness of the hair-free part of the front in the Indian female is in some instances very striking. It is not due generally, it may be said at once, to a low vault of the skull, but to a low extension of the hair.

In the American negro the female forehead in absolute height is even nearer that of the male than in the whites, and exceeds considerably that of the male relatively to stature. The small number of available negro subjects makes definite conclusions impossible, but the indications are very manifest.

Individual Differences

The height of the forehead in each group examined was found to show extensive individual variation. The range of this is shown in the figures below. It exceeds considerably that of facial height [1] and all other facial and head measurements, except ear length. As with most other dimensions, it is appreciably greater in the male than in the female. Racially, though the figures are affected by the unequal and in one or perhaps two cases by inadequate numbers of subjects, it is evidently greatest in the American Indian.

Causes

The data given in this paper show definitely that, in general, the height of the forehead is unaffected by mental development, but is subject not only to large individual but also to substantial racial and sex differences.

[1] See my *Old Americans*, 393–394.

RANGE OF INDIVIDUAL VARIATION IN HEIGHT OF FOREHEAD

	Males			
	Range of variation	Difference (d)	Mean (m)	Extent of variation $\left(\frac{d \times 100}{m}\right)$
Old Americans	(510) 5.1–8.3	3.2	6.58	*48.6*
American Indians	(1091) 4.0–8.4	4.4	6.64	*52.4*
Eskimo	(182) 5.3–8.6	3.3	7.16	*46.1*
American Negroes	(20) 5.2–8.1	2.9	6.98	*41.5*

	Females			
	Range of variation	Difference (d)	Mean (m)	Extent of variation $\left(\frac{d \times 100}{m}\right)$
Old Americans	(207) 5.2–7.8	2.6	6.45	*40.3*
American Indians	(453) 4.7–7.8	3.1	6.11	*50.7*
Eskimo	—	—	—	—
American Negroes	—	—	—	—

Both the race and the sex differences are of a peculiar nature. The race differences, except perhaps in the negro, show but little taxonomic (classificatory) value. They are apparently largely incidental. The sex differences are not harmonious in the different groups, which is exceptional. In the white and the negro they favor the female, in the American Indian [1] the condition is reversed.

[1] As well as in the Eskimo, according to my impression.

All this naturally stimulates the inquiry into the causes of these phenomena. And the first direction of the inquiry turns to the skull. Is not a low or high forehead conditioned by low or high frontal part of the skull? Observation shows that exceptionally low or high front is to some extent attended by low or high forehead in the living; but if such extremes are eliminated it soon becomes manifest that there is but little correlation between the two. What differs is not so much the height of the bony front as the extension downward of the hairline. The variation in the height of the forehead in the living is essentially a variation in the height of the hairline, regardless largely of the underlying skull.

What causes the variation in the normal hairline can only be determined by further research. It is certain that low or again high foreheads "run in families." And it is plausible to accept that under the influences of segregation, isolation, and perhaps some form of conscious or unconscious selection, lower or again higher foreheads may become generalized in a locality or in a racial group. The case of the Indians suggests that an important part may have been played by sexual selection.

In addition, some causes of different lowness or height of hair insertion over the forehead may possibly lie in the hair system itself, with its blood supply and innervation; but it would be difficult to state precisely any definite factors in this connection.

THE RELATION OF LEAF-SURFACE TO WOOD FORMATION IN PINE TREES

D. T. MACDOUGAL

(Read by title, April 20, 1933)

THE carbohydrates which originate by the photosynthetic processes in green leaves, are used in part as a source of energy in all parts of the plant, in the composition of living material, and in the construction of permanent structures such as the cellulose walls of woody elements.

In many plants carbohydrate is produced at a rate much in excess of that of its use in respiration and construction, the surplus being stored as starch in the parenchymatous cells of the medulla or pith and its rays.

In the consideration of this subject in connection with my studies of the processes of growth in trees, it was seen that surplus material piled up as comparatively enormous reserves in the redwood, and that much starch might be accumulated in many kinds of trees including some species of pine.

The Monterey pine, however, (*Pinus radiata*) which has been the subject of intensive dendrographic studies for fifteen years, accumulates but little starch. The wood was found to include no more than 0.146 per cent of soluble sugar. The whole system is one in which material formed in the leaves may be considered as being transported directly to elements newly derived from the cambium to be used chiefly as wall-material.

The proportion of the original material broken up in respiration probably varies within comparatively narrow limits. The total volume of the wood formed in a season may therefore be taken as a practical measure of the comparative photosynthetic activity of the leaves in any season or period.

The total volume of the woody material included in the trunk and branches of a pine tree may be calculated at any stage by the use of accepted formulæ. It has been found that

the volume of the root-system of the Monterey pine is equivalent to 1/7 to 1/4 that of the trunk and branches.

The volume of wood in the concentric shell added to all of these members in a season may be calculated from dendrographic records, and finally checked by estimations based on direct measurements when the tree is taken down for analysis.

In the analysis of the dendrographic records of several pine trees for periods of 10 to 15 years, the volume of the woody material in the root-system, trunk and branches was estimated from direct calibrations and later checked by weighing. The volume of the concentric shell of wood added to the trunk and in extensions of the trunk, roots, and branches in a season may be found with adequate exactness by the figures thus obtained.

Next the area of green surface of the leaves is to be ascertained. A basis of such calculations was obtained by defoliating a number of trees, the largest of which was over 60 feet in height. Counts of a number of small lots were made from which the total number of leaves was obtained. Finally, the average of the green surface being known as 109 sq. mm. for each leaf, the total green surface exposed to the sunlight may easily be made out. The determination of the amount of wood resulting from the activity of a unit area is readily ascertainable. In the figures given below, this is expressed as in terms of the thickness of the layer which would be formed if the woody material were spread over the entire green surface.

The areas of green surface presented by the Monterey pine have been calculated more accurately than has ever been done previously with any tree. The maximum in the trees under observation was seen in tree No. 28 of the dendrographic series, which was estimated to carry 10 million leaves in the three suites characteristic of this tree. This would imply that it exposed a total surface of 1090 sq. meters, or nearly 1200 square yards, or something more than a fourth of an acre. It may safely be taken for granted that the green surfaces of some individuals of this and other species of pines may exceed these areas. If the above information be restated for empha-

sis it may be said that a stand of 200 pine trees on an acre would expose a total green surface of 40 or 50 acres.

The use of the thickness of the concentric shells of wood formed every season as an index of climate, particularly total rain-fall, has been carried to great lengths by Douglass and others.[1] Such studies assume a dominating action of total yearly rainfall on growth, an assumption for which ample justification may be seen in certain trees under limited conditions.

The facts presented here are in a form which is based on the unescapable conclusion that the total products of photosynthesis of a tree which are converted into wood are a resultant of the action of a constellation of agencies, including total energy derived from light, temperature, soil-moisture supply, relative humidity, transpiration, and developmental stage of the tree. It is not to be expected that such results would exhibit anything but low correlations with records of precipitation however plotted.

If now, some examples of the above be cited, this will become plainly evident. A young tree, 5 meters in height in 1925, bore 130,000 leaves on which the woody material constructed in that year would be equivalent to a layer 0.2 mm. in thickness: 165,000 leaves were carried in 1926, on which wood formed was equivalent to a layer 0.35 mm. in thickness. The layer was 0.38 mm. on the green surfaces of the 200,000 leaves carried in 1927. The amount of wood formation rose to 0.5 mm. in thickness on the 260,000 leaves carried in 1928. The wood of 1929 made up a thinner layer 0.3 mm. in thickness on the 335,000 leaves carried. The woody material of 1930 would have been equivalent to a layer 0.38 mm. in thickness on the surfaces of 420,000 leaves present during the season.

The results obtained from another young tree, No. 20, 5.2 meters in height and 8 years old at the beginning of 1923, offer profitable comparisons as this was a much more active individual. The wood of 1923 was equivalent to a layer 0.56

[1] Douglass, A. E., "Evidences of Cycles in Tree Rings," *Proc. Nat. Acad. Sc.*, 19, No. 3, 350–360, 1933.

mm. in thickness on the 220,000 leaves carried in that year. The layer of 1924 was 1.3 mm. in thickness on 300,000 leaves: the layer of 1925 was 0.87 mm. in thickness on 320,000 leaves: the layer of 1926, 1.07 mm. in thickness on 450,000 leaves: that of 1927, 0.93 mm. in thickness on 600,000 leaves: that of 1928, 0.84 mm. on 750,000 leaves: that of 1929, 0.60 mm. in thickness on 939,500 leaves: that of 1930, 0.46 mm. in thickness on 1,479,500, leaves: that of 1931, 0.33 mm. in thickness on 2,339,500 leaves: that of 1932, 0.27 mm. in thickness on the 3 million leaves present. The last leaf-census was determined from actual weights and counts. As each leaf is carried at least three years it was estimated that the photosynthetic operations amounted to something over 10 million leaf-years. An average of 171 cu. mm. of fresh woody material was produced by every leaf during the 3-year period of its existence. Otherwise expressed, the tree with a total volume of 614,000 cc. of woody material represents the activity of an average leaf for 10,772,000 years. Such estimates are possible only when the development of the tree is followed for several years and it is taken down for final leaf-census and for determination of the total volume of woody material. This was also done with No. 17 as described below.

It will be most profitable, however, to discuss next the operations of tree No. 1, the dendrographic measurements of which were begun in August 1918, and the continuous record of changes in diameter is now nearing the end of the fifteenth year.

The woody layer in 1919 was 0.43 mm. on 4 million leaves: 0.42 mm. on 4,250,000 leaves in 1920: 0.68 mm. on 4,450,000 leaves in 1921: 0.49 mm. on 4,700,000 leaves in 1922: 0.24 mm. on 4,900,000 leaves in 1923: 0.22 mm. on 5,100,000 leaves in 1924. The heavy layer in 1921 was partly due to irrigation in mid-summer after growth had ceased. The tree was similarly irrigated in 1925. An amount of wood equivalent to a layer 0.10 mm. in thickness had been formed by June 1st. The additional growth brought this up to 0.30 mm. with 5,400,000 leaves present. A layer of 0.27 mm. in thickness on 5,700,000

leaves was formed in 1926. The layer of 1927 was 0.24 mm. in thickness on 6 million leaves: that of 1928 was 0.21 mm. in thickness on 6,400,000 leaves: that of 1929, 0.22 mm. in thickness on 6,900,000 leaves. A notable increase to 0.33 mm. on 7,400,000 leaves occurred in 1930: a decrease to 0.17 mm. on 7,700,000 leaves took place in 1931, while a minimum of 0.12 mm. on 8 million leaves was found in 1932. It is suggested that the tree was near the apex of its developmental activity and that the net average product of each leaf in wood was now due to undergo an irregular decrease following maturity.

Lessened productivity with age is illustrated by the results of observations on No. 28, which is nearing the age-limit in 1933, at which time it is estimated to be in its 85th year.

The layer formed in 1921 in the 73d year was 0.14 mm. in thickness: 0.26 mm. in 1922: 0.16 mm. in 1923: 0.09 mm. in 1924: 0.13 mm. in 1925: 0.12 mm. in 1926: 0.18 mm. in 1927: 0.06 mm. in 1928: 0.08 mm. in 1929, and a similar amount in 1930: 0.05 mm. in 1931 and 0.09 mm. in 1932.

The tree had reached maturity, and had a broadened dome-shaped crown before the observations were begun. Estimates based on counts of all other trees justify the assumption that the tree carried about 10 million leaves during the 12 year period of the measurements given above.

The data obtained by observations on Monterey pine No. 17 illustrate the action of a tree showing the highest measured rate of cellulose formation, and which also showed continuous growth during three seasons.

This tree stood on the margin of a swamp and having at all times an adequate water-supply, the principal limiting factor was illumination, which in this region is lessened by fogs rather than by cloudiness.

No. 17 was 15 years old at the beginning of 1923. In that year a layer of 0.96 mm. was added to the area of the surface of the leaves which were estimated at 550,000 in number. The season of 1924 was one of deficient rainfall, a minimum prevalence of fogs, and consequently a maximum exposure to sunlight. Consequently, an amount of wood was formed

which would be equivalent to a layer 1.73 mm. in thickness on the surfaces of the 750,000 leaves carried.

A precipitation in 1925 double that of 1924, with implied increase in cloudiness and in fogs, was accompanied by the formation of wood amounting to 1.58 mm. in thickness on the surfaces of a million leaves. Production of wood resulted in a similar layer on 1,300,000 leaves in 1926, during which season the precipitation was slightly in excess of that in 1925.

Still greater precipitation in 1927 was accompanied by a slightly reduced layer 1.5 mm. in thickness on 1,700,000 leaves. Precipitation was less in 1928 than in 1927, but no record of cloudiness or temperature can be given. The woody layer was 1.08 mm. in thickness on 2,200,000 leaves.

The precipitation in 1929 was also less than that in 1928, with no record of temperature or of illumination. The layer was 1.01 mm. in thickness on 2,800,000 leaves.

The highest efficiency of the leaves was in 1925, in which wood equivalent to a layer 1.58 mm. in thickness on the leaf-surfaces was formed. The total volume of the wood was however but 141,500 cc.

The performance of the tree as a whole with a much greater number of leaves reached a maximum of 309,300 cc. in 1929. This is equivalent to over 130 board feet. The productivity of the cellulose-forming activity of this tree may be emphasized by saying that it constructed enough woody material in 1929 to form a board a foot wide, an inch thick, and more than double its own height.

While the main thesis of this paper is the net product of photosynthetic surfaces, it is of interest to note the performance of average single leaves, which have a surface area of 109 sq. mm. These leaves begin to develop in January, reach full size by June and them are cast off in October or November two years later, having an active existence through three seasons. The seasonal net product of a leaf in moist wood is on the average about equal to the volume of the leaf, which thus during its life-time produces about three times its own volume of moist wood.

Recapitulation

The facts cited above were obtained from five trees of the Monterey pine. The observations on Nos. 19 and 20 were made between the ages of 8 and 18 years. These two individuals were under conditions similar to those of two older ones, Nos. 1 and 28

The amount of wood calculated as a layer on the green surfaces of the leaves varied in 1925 to 1930 from 0.20 mm. to 0.38 mm. annually in No. 19: the thickness of such a layer ranged from 0.27 to 1.30 mm. during the period of 1923–1932. The maximum layer of 1.30 mm. was laid down by No. 20 in 1924. A minimum of 1.07 mm. was shown by this tree in 1926. A maximum of 0.50 mm. was shown by No. 19 in 1928. The minimum of 0.27 mm. in No. 20 occurred in 1932.

The thickness of the layer as applied to green surfaces of No. 1 varied from 0.49 mm. to 0.12 mm. 1919–1932. (A heightened maximum of 0.68 mm. by irrigation was produced in 1921). The normal maximum occurred in 1922: the minimum occurred in 1932.

The oldest tree, No. 28, showed a variation from 0.20 mm. to 0.05 mm. 1921–1932. The maximum occurred in 1922, the minimum in 1931.

Comparisons in this quartette of trees growing under similar conditions do not reveal many agreements or cases of coincidental action. The younger trees differed most widely. The maximum in the two older trees occurred in 1922 but the minimum came in 1931, while the minimum of No. 1 was in 1932. The consistently low rate in the old tree suggests an end to be reached within a few years as trees of this species rarely attain an age of a hundred years. The irregularly lessening rate in No. 1, now about 45 years old, is that consequent upon maturity. The average rate in No. 1 from its 30th to its 45th year was 0.23 mm. annually, while that of No. 28 from its 73d to 85th year was half this amount, or 0.115 mm.

The record of No. 17 which was a case of a tree with a continuously adequate supply of water showing the formation of

an amount of wood which would have formed layers 0.96, 1.73, 1.58, 1.50, 1.08 mm., and 1.09 mm. in thickness, in the seasons 1923–1929, with an average of 1.27 mm. The maximum occurred in a season with a maximum amount of sunlight and deficient rainfall.

It is obvious that the amount of the net product in the form of woody material of a unit area of green surface is affected by a number of conditions. It may be taken for granted that the amount of energy received in sunlight is a prime factor, that a soil water supply is scarcely second in importance.

The amount of wood produced by a unit leaf-area in an old (and large) tree is less than in a young tree. It seems reasonable to assume that much more energy is used in lifting water and in translocation of photosynthetic products in such trees. No available information gives grounds for any conclusions as to lesser efficiency of leaves on old or large trees.

The record of Monterey pine No. 17 includes maximum measurements for the production of woody material per unit of green surface, for single leaves, and for individual trees.

FURTHER EXPERIMENTS ON THE CONTINUOUS GENERATION OF HEAT IN CERTAIN SILICATES *

ELMER A. HARRINGTON †

(*Read April 22, 1933*)

ABSTRACT

The existence of a continuous generation of heat in certain silicates has been investigated by putting the material in a well-insulated calorimeter supported in a jacket maintained at 0° C. Temperature differences between calorimeter and jacket were observed by a thermoelement connected directly to a sensitive galvanometer. For a few materials a positive result was indicated. Some consequences of such a result have been examined.

CONTENTS

I. INTRODUCTION

THE discovery by the late Dr. Charles F. Brush [1] of the spontaneous generation of heat in recently hardened steel led him to carry out a series of investigations of basalts, lavas,

* Published by permission of the Director of the U. S. Bureau of Standards.
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minerals, artificial silicates, etc., in an attempt to establish the existence of such a source of heat in the materials forming the earth's crust. Dr. Brush measured the temperature at the center of the material in a Dewar flask referred to the temperature of an ice bath when both the Dewar flask and the ice bath were in a space kept at 0° C. The technique employed in these experiments was apparently good, and the precautions taken to eliminate experimental errors were numerous and appropriate. The possibility remained, however, that the positive result found was due to some purely experimental error, and Dr. Brush accordingly sponsored the performance of further experiments at the Bureau of Standards. It was recognized also that it would be advantageous to employ methods and apparatus of a different kind, rather than merely to duplicate the earlier experiments. The description of the later experiments constitutes the subject matter of this paper.

Dr. Brush realized that his results were received with considerable skepticism, and was somewhat concerned lest preconceived ideas of the investigator should influence the findings. The measurements were accordingly undertaken as a purely experimental investigation, the magnitude of the effect to be looked for being known from the results of Dr. Brush's work, and the calculations described later in this paper were not made until after the experimental work was completed.

II. Description of Method and Apparatus

a. The Calorimeter

The fundamental part of the apparatus was a calorimeter so designed that a sample of the material was so thoroughly isolated from external influences that any appreciable generation of heat in the material might be observed as a rise of temperature of the calorimeter. The apparatus was arranged to permit measurements of temperatures over long periods of time and also, when desired, measurements of the exchange of energy between the calorimeter and its surroundings.

The calorimeter consisted of a brass cylinder 10.6 cm. long, 7.8 cm. inside diameter, and 0.3 cm. wall thickness, containing the parts necessary for introducing energy and for measuring small temperature differences. Its construction may be seen by reference to the illustrations:

Figure 1 is a photograph of the unassembled parts of the calorimeter, while Fig. 2 shows the whole apparatus in section.

The calorimeter could be used with either of two covers, one (Fig. 1, *A*) to close off the calorimeter, and the other (*B*) to allow the calorimeter and the jacket to be exhausted simultaneously. The joint between the calorimeter and cover *A* was made tight by a lead wire gasket. The calorimeter was exhausted by connecting it to a vacuum pump by a glass tube sealed over the small copper tube ($A - 1$) with Khotinsky cement. This glass tube was sealed off near the copper tube when exhaustion was sufficiently complete. Cover *A* was always used when it was desired to exhaust the calorimeter separately from the jacket.

To promote uniformity of temperature in the calorimeter a heat distributing system (*D*) was installed. This system consisted of a set of sixteen brass plates about 8 cm. long, eight of which were soldered to a central brass tube so that the plates were radial and parallel to the axis of the calorimeter. The heating coil (*E*), in which electric energy could be converted into heat added to the calorimeter system, fitted closely into the central tube. The outer edges of all of the plates were soldered to a brass tube which fitted snugly into the calorimeter and made good thermal contact with it. Thus the maximum distance from any point in the material under investigation to some point in the metal was comparatively small (not over 4 mm.). In this way a uniform temperature distribution throughout the material was obtained.

The copper wires (No. 32) leading to the heating coil passed through a sealed joint in the Bakelite cap ($A - 2$) in the cover, and were connected to thermal "tie-downs" [2] (*TD*) on the inside of the jacket, the object of which was to prevent

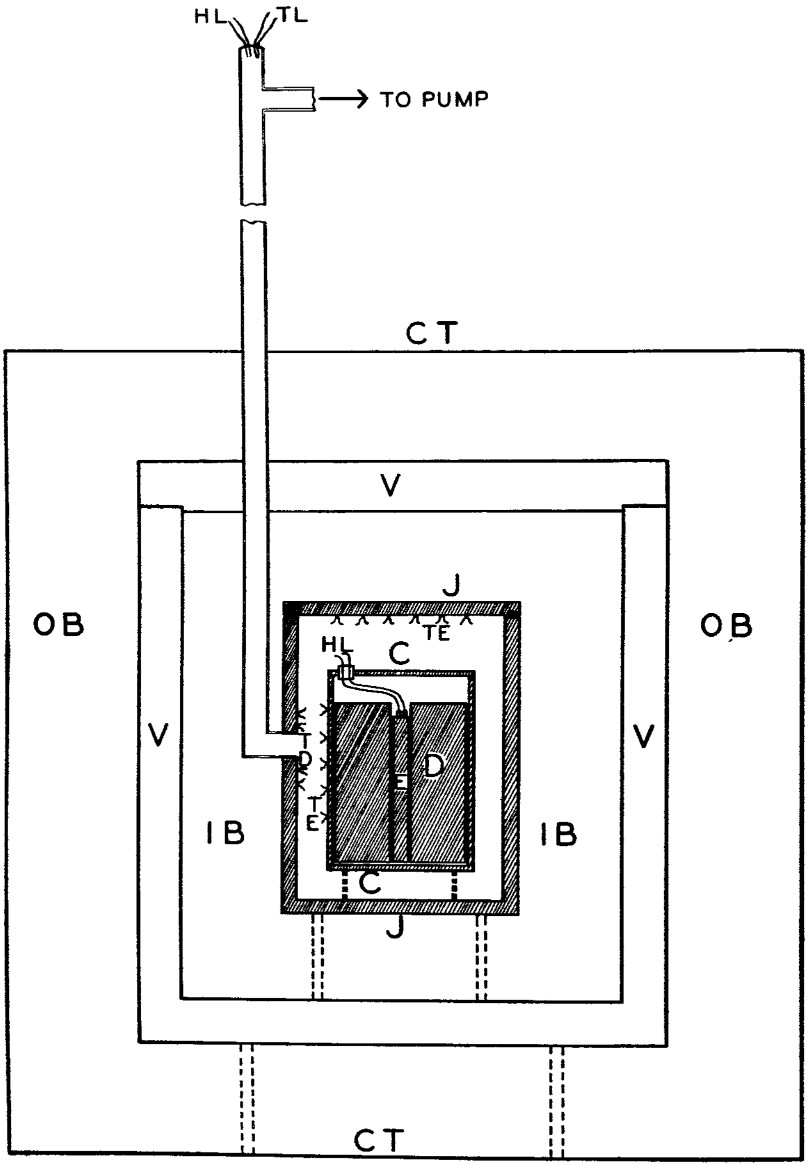

Fig. 1.

heat conduction along the wires from the outside. The heater leads (HL) passed through a Khotinsky joint from the vacuum system to the outside.

b. The Jacket

The calorimeter was supported by three small ivory pins which were fitted into metal supports soldered to the bottom of a cylindrical jacket (J), Fig. 1, which was made of heavy brass tubing 0.8 cm. thick, 16.5 cm. long, and 12 cm. inside diameter. Its cover rested on a lead gasket and was held down by 30 screws.

The jacket provided the means of isolating the calorimeter from extraneous sources of energy. The space between the

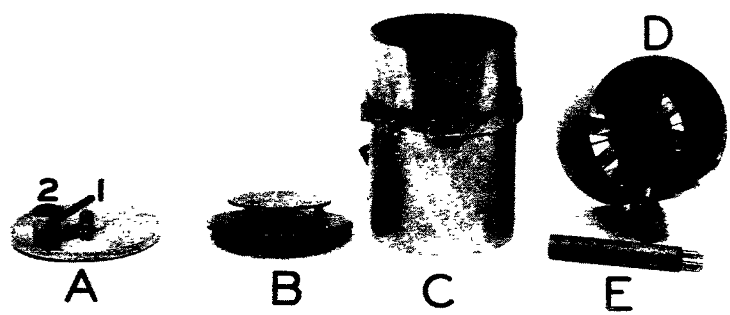

FIG. 2.

calorimeter and the jacket was evacuated through a side-tube in the jacket by means of a two-stage mercury vacuum pump. Heat leakage by radiation from the calorimeter was minimized by heavily nickel-plating and highly polishing the outer surface of the calorimeter and the inner surface of the jacket, while the flow of heat along the necessary metal connections was made extremely small by using fine wires.

c. The Ice Bath

An ice bath, the function of which was to control the jacket temperature, was contained in a cylindrical copper tank (CT)

18 inches deep and 18 inches in diameter. This bath was divided into two sections—an inner bath (*IB*) and an outer bath (*OB*)—by a double-walled insulated vessel (*V*). The inner cylinder of this double-walled vessel was 10 inches in diameter and 11 inches high, while the outer cylinder was 12 inches in diameter and 12 inches high. The inclosed space, one inch wide, between these cylinders was filled with mineral wool. There was also a double-walled insulated cover. This insulated vessel, with the calorimeter and its jacket supported centrally within it, was packed with a mixture of water and lumps of ice about the size of chestnuts, and the cover was put on. The whole was then placed in the larger tank so as to provide a space about three inches wide all around which was filled with ice and water. With this arrangement the temperature of the jacket remained extremely constant. A drain was installed in the side of the copper tank to keep the level of the ice-water in the outer bath about an inch above the top of the insulated vessel.

The copper tank was entirely surrounded by more than four inches of good insulating material, all of which was contained in a wooden box.

d. Thermoelement Installation

The mean surface temperature of the calorimeter relative to that of the jacket was measured by a differential multiple thermoelement (*TE*) with one set of junctions distributed on the outside of the calorimeter and the other set on the under side of the jacket cover. The multiple thermoelement consisted of five pairs of chromel and copel wires (No. 32). Chromel and copel were chosen because of their comparatively high thermoelectric power and relatively low thermal conductivity. Samples of the wires were calibrated at 5°, 10°, 15°, 50°, and 100° C., and were found to have a thermo-electromotive force at temperatures near 0° C. of 58 microvolts/° C., so that for the multiple thermoelement 1 microvolt corresponded to 0.00345° C. The total resistance of the thermoelement was 77 ohms.

The method of constructing the thermoelements and of attaching them to the chosen points on the apparatus was devised and described in detail by Osborne, Stimson, and Fiock.[2] Each of the two copper wires (No. 32) leading from the thermoelement through the exhaust tube to the outside at (*TL*) was connected to two thermal "tie-downs" on the jacket to intercept heat conduction from the outside.

e. Accessory Apparatus

Since the temperature differences to be measured by the thermoelement were very small, observations were made by direct galvanometer deflections. A Leeds and Northrup type HS galvanometer, having an external critical damping resistance of about 80 ohms, was connected to the thermoelement through a copper-wire reversing switch similar in principle to one used by Dr. Brush.[1] The scale for observing the deflections was mounted at a distance of 2 meters from the galvanometer. The sensitivity of the galvanometer under these conditions was 9.8 mm./microvolt, a value which did not change more than 1 per cent during the entire period of its use. Thus, 1 mm. deflection (2 mm. on reversal) on the scale was equivalent to a difference of temperature between the calorimeter and the jacket of 0.00035° C.

III. The Materials

The materials investigated in this apparatus were complex silicates or silica,—Sandusky clay, cobalt-nickel silicate, beryl crystal, beryl ore, quartz crystal, and Ottawa sand. The clay and the double silicate of cobalt and nickel were provided by Dr. Brush; the beryl crystal, the beryl ore, and the quartz crystal were furnished by Mr. C. B. Sawyer of The Brush Laboratories Company of Cleveland, Ohio; and the Ottawa sand was obtained from the Clay and Silicate Products division of this Bureau.

Petrographical analyses of these materials yielded the following information:

Sandusky clay—mostly clay mineral (kaolinite, *i.e.*, hydrated aluminum silicate), some quartz, a little calcite, and a very little hydrated ferric oxide.

Cobalt-nickel silicate—nearly pure, with a very little sodium silicate.

Beryl crystal—pure beryllium aluminum silicate.

Beryl ore—mineral beryl (nearly all beryllium aluminum silicate).

Quartz crystal—pure silica.

Ottawa sand—practically pure silica.

Each of these materials was compared, as regards radioactivity, with uranium oxide, and the comparison in each case indicated that the material was entirely inactive—certainly having an activity less than 1 per cent of the alpha ray activity of uranium oxide.

The Sandusky clay was prepared by Dr. Brush in 1926 by washing it free from sand and coarse particles and by air-drying at room temperature to leave it in its natural condition. It was tested by Dr. Brush in 1926, and gave "moderate but undoubted heat generation." He tested it again early in 1927, and found "no change in its activity." (Dr. Brush stated that he "could easily have detected a change of 10 per cent in its heat generating activity.")

The clay used in the present experiments had been exposed to the atmosphere of the laboratory for over two years. It was not dried at all before being put in the calorimeter, and it was broken between the fingers only enough to allow the pieces to go between the plates of the heat distributing system; fine or powdered material was sifted out. The clay was pushed down with the fingers, but in no case was it pounded. About 310 grams, or 120 $cm.^3$, of the clay was sufficient to fill the calorimeter.

The cobalt-nickel silicate was prepared by Dr. Brush in October, 1926, "by precipitating a dilute solution of cobalt and nickel sulphates with a dilute solution of sodium silicate in slight excess; boiling to insure complete reaction; washing and filtering the precipitate to get rid of soluble impurities;

and drying it in a hot air bath until it ceased to lose weight." The sample investigated was kept in a paper box, not sealed; and contained a very little hygroscopic moisture. 180 grams of it were used in the calorimeter.

The beryl crystal was a very good one, about 6 cm. in diameter and 5 cm. high, weighing 450 grams. It was chosen from several samples because of its good appearance and excellent condition, and because it filled quite well the space in the calorimeter when the heat distributing system was removed. Cover *B* was used on the calorimeter in this case, and the calorimeter and the jacket were exhausted at the same time.

The beryl ore had been broken into pieces varying in size from 2 mm. to 10 mm. About 500 grams of it were used. The ore was dried in an oven at 98° C. for twenty-four hours, when the cover was put on, and the calorimeter exhausted while it was still hot.

The quartz crystal was selected for its size and condition. It was about 6 cm. in diameter and 8 cm. long, and weighed 410 grams. It was a clear, unpolished specimen, and did not appear to have been crushed or abraded. Cover *B* was used when investigating this material.

The Ottawa sand was grade *A*, and it consisted of uniform grains between No. 20 and No. 30 mesh. 500 grams of it were used in the calorimeter.

IV. Measurements and Results

a. Experimental Procedure

The experimental procedure was as follows: For a blank run the empty calorimeter was put in the jacket, which was exhausted and tested for leaks. Air was next let into the jacket until the pressure was about 1 cm.; ice was then put in the baths, and the apparatus allowed to stand until uniform temperature distribution was obtained, as indicated by zero deflection of the thermoelement galvanometer. The calorimeter and the jacket were exhausted again. This produced at first a slight cooling of the calorimeter due to adiabatic

expansion of the air in it, but radiation from the jacket heated the calorimeter in a day or two to 0° C., and this temperature could be held indefinitely. Each day during the course of the experiment a few lumps of ice from the outer bath were added to the inner bath. This ice had been in contact with water since the preceding day and its temperature could not have differed materially from 0° C. Then freshly cracked ice was added to the outer bath. Readings of room temperature, pressure in the apparatus, and galvanometer deflections were made several times daily. The following are typical of a day's observations:

Blank Run (Calorimeter Empty)

November 9, 1929

Time	Room Temperature	Pressure in Jacket	Scale Reading, Reversing Switch: Open	Normal	Reverse	Average Deflection	Temperature Difference (Calorimeter minus Jacket)
A.M.	° C.	mm.	cm.	cm.	cm.	mm.	° C.
8:30	20.0	<0.0001	0	+0.05	+0.05	0	0
11:20	22.0	"	0	−0.05	−0.05	0	0
P.M.							
1:00	24.0	"	0	−0.03	0	−0.1	−0.00004
3:00	24.5	"	0	−0.03	−0.02	−0.1	−0.00004
4:10	—	"	0	0	−0.04	+0.2	+0.00007

Ice was added at 8:45 A.M.

A similar procedure was followed when investigating the several materials. The calorimeter was filled with the material and the air was exhausted until the pressure was of the order of 0.001 mm. The calorimeter was then sealed off and put in the jacket. A typical day's observations are given in the following table.

b. *Determination of Heat Leakage*

To correlate temperature differences in terms of rate of heat leakage, the calorimeter was electrically calibrated. This was done as follows. A measured current was passed through the heating coil in the calorimeter for two days, and

Sandusky Clay

May 21, 1929

Time	Room Temperature	Pressure in Jacket	Scale Reading: Reversing Switch: Open	Normal	Reverse	Average Deflection	Temperature Difference (Calorimeter minus Jacket)
A.M.	° C.	mm.	cm.	cm.	cm.	mm.	° C.
8:30	22.0	<0.0001	0	+0.45	−0.41	4.3	0.0015
12:00 M.	22.0	"	0	+0.42	−0.40	4.1	0.0014
P.M.							
2:40	22.5	"	0	+0.43	−0.37	4.0	0.0014
4:15	23.0	"	0	+0.44	−0.42	4.3	0.0015

Ice was added at 8:40 A.M.

then increased a little and held for three days. Galvanometer deflections due to temperature differences between calorimeter and jacket were observed several times each day. From these data and the resistance (R) of the heating coil the rate of electrical energy input to maintain a difference of 1° C. between the calorimeter and the jacket could be calculated. The data follow:

Trial	Current (I) (Microamperes)	Deflection (D) (mm.)	Temperature Difference ° C.
a	620	37.6	0.0142
b	680	45.0	0.0158

Resistance of heating coil = 936 ohms

$$(a)\qquad \frac{I_1^2R}{D_1} = \frac{(620\cdot 10^{-6})^2 \times 936}{37.6} = 9.6\cdot 10^{-6} \text{ watts/mm.}$$

$$(b)\qquad \frac{I_2^2R}{D_2} = \frac{(680\cdot 10^{-6})^2 \times 936}{45.0} = 9.7\cdot 10^{-6} \text{ watts/mm.}$$

Since a deflection of 1 mm. was equivalent to a rise of temperature of 0.00035° C., the rate of electrical energy input, or the rate at which energy must have been generated in the material, to maintain a constant difference of temperature of 1° C., was $9.6\cdot 10^{-6}/3.5\cdot 10^{-4} = 2.7\cdot 10^{-2}$ watts.

Therefore the rate of generation of energy required to maintain a difference of temperature of 0.0015° C. was $2.7 \cdot 10^{-2} \times 1.5 \cdot 10^{-3} = 4.0 \cdot 10^{-5}$ watts.

If the rate of heat loss from the calorimeter when the temperature difference was 0.0015° C. is calculated from the physical characteristics of the calorimeter, it is found that the rate of loss by conduction along the ivory pins, the thermocouple wires, the heater lead wires, and through the residual air is negligibly small compared with the rate of loss by radiation. It can be shown that a value of the emissivity between 0.15 and 0.20 would account for the observed rate of heat loss.

c. Experimental Results

Observations of the room temperature, of the pressure in the jacket, and of the temperature difference between the calorimeter and the jacket were recorded from three to six times each day. The room temperature was usually between 22° C. and 26° C., and the pressure in the jacket was always less than 0.0001 mm. The variation of the temperature difference during the day seldom exceeded 0.0005° C.

The experimental results are shown graphically in Fig. 3, where each point represents the average of a day's observations of temperature differences. Beginning at the bottom of the figure, the average temperature differences are plotted for the cases when the calorimeter was empty and when it contained Sandusky clay, cobalt-nickel silicate, beryl ore, quartz crystal, Ottawa sand, or beryl crystal. (In case of the beryl ore the points represent observations taken on alternate days.)

The precision of the experiments indicated by the results in the blank run is of the order of 0.0002° C. Where a positive result is indicated (as in Sandusky clay) the variation from time to time was greater than in the blank run, and the results were even erratic at times, so that an average value of the temperature rise determined from the observations is subject to a very large error.

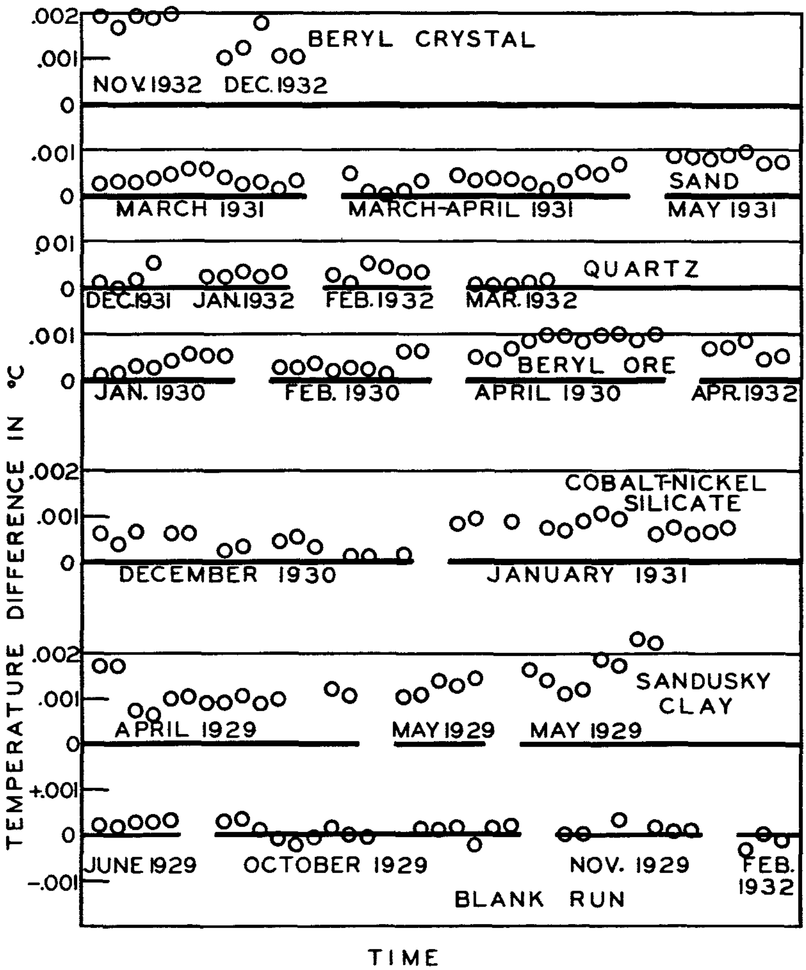

FIG. 3.

A break in the continuity of the observations is indicated by a break in the reference line. In the blank run the jacket was not opened between June and November, 1929, and the observations during that period correspond to but one assembling of the apparatus.

The investigation of Sandusky clay was interrupted twice —once to determine the heat leakage, and once to repair a

leak in the vacuum system—but the calorimeter was not disturbed at all during the course of the experiment.

The observations of cobalt-nickel silicate were interrupted once by a leak in the vacuum system, but the jacket was not opened.

Three separate investigations of beryl ore were made, the first being interrupted for a few days by a crack in the glass tube leading from the apparatus to the mercury pump.

The observations on quartz were preceded by a blank run (not shown in Fig. 3). They were also interrupted in January, 1932, to install a new thermoelement and to conduct a blank run (shown in figure), and again in February to repair a leak in the jacket.

The investigations of Ottawa sand were interrupted in March, 1931, to repair a leak, but the calorimeter was not disturbed at that time. In May, 1931, air was let into the calorimeter, and the calorimeter and jacket were exhausted at the same time, and the observations in May followed.

When the beryl crystal was used the observations were not interrupted.

Positive results are indicated in Sandusky clay and in beryl crystal, and perhaps in beryl ore and cobalt-nickel silicate, but the effect in Ottawa sand and in quartz crystal appears to be zero at times and positive at other times.

d. Comparison with Results Obtained by Dr. Brush

The conditions under which the temperatures were observed in the Brush and in the Bureau of Standards apparatus were materially different. Dr. Brush measured the temperature at the center of the material in the calorimeter referred to the temperature of the ice bath when the space containing the calorimeter and the ice bath was kept at 0° C., while the temperature in the present experiments was determined at the surface of the calorimeter. Sandusky clay was chosen for this comparison because Dr. Brush[1] attached "much importance to the Sandusky clay experiment because it doubtless represents clays in general," and because the radioactivity of clays in general is extremely low.

It can be shown by the theory of heat conduction that, for a cylinder of material as used in either the Brush calorimeter or the Bureau of Standards calorimeter without a diffusion system, the difference of temperature between the center and the surface is given by the equation

$$t_c - t_s = \frac{a}{4K} r^2,$$

where r = radius of calorimeter = 4 cm. (approx.),
K = conductivity of the clay = 0.001 watt/cm. °C.
a = heat generated in watts per cm.^{3} of the clay.

Since the observations indicated that the 125 cm.^{3} of clay used in the Bureau of Standards calorimeter generated heat at the rate of $4.0 \cdot 10^{-5}$ watts, the corresponding value of a is $3.2 \cdot 10^{-7}$ watts/cm.^{3}.

If it be assumed that the same value of "a" applies to the clay used in Dr. Brush's experiments, it would follow that the 350 cm.^{3} of clay used in his calorimeter would have generated heat at the rate of $1.12 \cdot 10^{-4}$ watts or 0.086 calories/hour. Using the value of the heat transfer coefficient (13.7 calories/hour °C.) obtained by Dr. Brush, the temperature (t_c) at the center of the clay in the Brush calorimeter was calculated to be approximately 0.007° C. above the temperature of the ice bath. This result is of the same order of magnitude as the "excess" of temperature for the clay observed by Dr. Brush,[1] *i.e.*, t = 0.0136° C. The results of the present experiment are therefore substantially in agreement with those found by Dr. Brush.

e. Discussion of Results

The positive results obtained in these experiments and in those of Dr. Brush are too large to permit of their being reconciled with the known facts concerning the temperature gradients existing near the surface of the earth's crust. Assume, for example, that a large flat section of the earth were covered with a slab of clay of thickness L (in cm.) and of conductivity K = 0.005 watts/cm. °C., and that heat

were generated in it at the rate $a = 3.2 \cdot 10^{-7}$ watts/cm.^{3}. After a steady state had been reached no heat would be lost from the bottom, and if the upper surface were kept at 0° C., the temperature at the bottom of the slab would be given by the equation

$$t = \frac{a}{2K} L^2.$$

Thus, if $L = 3000$ cm. (100 feet), the temperature at the bottom of the slab would be

$$t = \frac{3.2 \cdot 10^{-7}}{2 \times 0.005} \times (3 \cdot 10^3)^2 = 300° \text{ C. (approx.)}.$$

There seems to be no escape from the conclusion that, if the effects observed in these experiments and in those of Dr. Brush are real, and not the result of some undiscovered experimental error, they cannot be characteristic of any appreciable mass of material in the earth's crust. In fact, a value of "a" consistent with the known facts about temperature gradients in the earth's crust ($a = 1 \cdot 10^{-12}$ watts/cm.^{3}) would require that the temperature differences to be expected either in these experiments or in those of Dr. Brush should be of the order of $1 \cdot 10^{-7}$ °C.

Bacterial action in the clay may have caused part of the heating effect in that material, even under high vacuum. If heat were generated in that way the amount would have been relatively greater (larger value of "a") for small quantities of material than for large. However, such a source of heat probably did not exist in the other substances investigated.

In conclusion, a positive heating effect was indicated for which there is no complete explanation. The fact that the indicated effect was observed both in the experiments of Dr. Brush and in those of the Bureau of Standards lessens the probability that it was due to experimental error. Therefore, while not excluding the contingency of experimental error common to the two methods accounting for the effect, the possibility remains that it may be due to some process as yet unknown.

Acknowledgments

The author desires to express his appreciation to all who aided in this investigation. The idea was original with Dr. Charles F. Brush, and he not only supported generously the work at the Bureau of Standards, but he also contributed much by his active interest and advice. Dr. Brush's heirs, Mr. Roger G. Perkins and Mrs. Dorothy Brush Dick, made it possible to continue the work. Mr. E. F. Mueller, under whose direction the experiments were performed, and Dr. M. S. Van Dusen made many valuable suggestions during the course of the investigation and in the interpretation of the results. Miss C. L. Torrey examined the materials for radioactivity and Dr. H. Insley made the petrographic analyses.

References

1. Charles F. Brush, *Proc. Am. Phil. Soc.*, 54, p. 154, 1915; 65, p. 207, 1926; 66, p. 251, 1927; 67, p. 105, 1928; 68, p. 55, 1929.
2. N. S. Osborne, H. F. Stimson, and E. F. Fiock, *Bureau of Standards Journal of Research*, 5, p. 411, 1930; R. P. No. 209.

STANDARD PHOTOMETRIC AND VISUAL SCALES OF MAGNITUDE

R. H. TUCKER

THE following comparison of differences of magnitude presents an almost perfect alignment of the relative magnitude scales. The magnitudes of the Preliminary General Catalogue of Boss were furnished by the late Dr. S. C. Chandler, from his own extensive research upon stellar estimates, and are undoubtedly as consistent and complete as any possible standard of visual estimates to the limit at grade 6.5. The magnitudes of the San Luis Catalogue of southern stars were taken from the Harvard College Observatory photometric measures for the greater part of the bright stars, with supplementary observations at San Luis for the faint stars.

In the first table of differences the first group of stars includes those estimated as brighter than first magnitude at San Luis, and the second group includes the estimates between first and second magnitudes. The final group includes estimates of eighth magnitude and of fainter ones. The tabulation with the P. G. C. as standard is arranged in the same manner. In both tables the mean differences are taken out in the same sense, San Luis minus P. G. C. The numbers of stars in each group, at intervals of one-tenth, show the variations to be expected from the existence of accidental errors of observation, and the summations of stars to each grade follow the trend of the differences of magnitude. The distribution of the stars in the photometric count shows an average excess of 6 stars in counts of even over odd tenths—a predeliction in those estimates for the use of the even figures. No sensible excess is shown in the counts of this visual scale.

The two scales evidently are in agreement at grade 4½, where the differences are close to zero, and the numbers in the two standards are close to 400 each. The photometric es-

timates are fainter and the corresponding summations are smaller above grade 4½, while these conditions are reversed below that grade. The end of precise comparisons by summations is reached at grade 5.9, the limit of the full count of stars in the P. G. C.

Represented graphically, a straight inclined line would follow the plot of mean differences closely, from the groups of bright stars fully to seventh magnitude. Below that point the comparisons are scattering, besides being beyond the reach

San Luis Catalogue

Mag.	Diff.	Stars	Sum	Mag.	Diff.	Stars	Sum
0.6	+44	5	5				
1.6	+26	13	18	5.0	−07	73	714
2.0	+25	4	22	1	−11	77	791
1	+30	3	25	2	−11	86	877
2	+31	7	32	3	−11	90	967
3	+30	2	34	4	−13	116	1083
4	+23	3	37	5	−14	98	1181
5	+20	3	40	6	−15	140	1321
6	+23	4	44	7	−15	123	1444
7	+13	4	48	8	−16	155	1599
8	+12	9	57	9	−15	89	1688
9	+17	12	69	6.0	−18	72	1760
3.0	+18	12	81	1	−22	57	1817
1	+17	11	92	2	−25	53	1870
2	+14	12	104	3	−26	54	1924
3	+13	9	113	4	−30	60	1984
4	+09	15	128	5	−32	37	2021
5	+08	6	134	6	−31	51	2072
6	+11	22	156	7	−32	47	2119
7	+09	14	170	8	−26	31	2150
8	+08	26	196	9	−29	30	2180
9	+05	14	210	7.0	−33	27	2207
4.0	+03	25	235	1	−27	11	2218
1	+03	40	275	2	−18	15	2233
2	+05	32	307	3	−28	15	2248
3	+02	33	340	4	−32	10	2258
4	+01	43	383	5	−17	6	2264
5	−02	41	424	6	−04	5	2269
6	−01	46	470	7	−30	2	2271
7	−03	48	518	8	x	x	x
8	−04	59	577	9	−40	1	2272
9	−07	64	641	8.2	(−10)	11	2283

PRELIMINARY GENERAL CATALOGUE

Mag.	Diff.	Stars	Sum	Mag.	Diff.	Stars	Sum
0.4	+41	7	7				
				5.0	−06	59	662
1.5	+30	20	27	1	−08	61	723
				2	−10	63	786
2.0	+22	6	33	3	−10	93	879
1	+23	3	36	4	−12	81	960
2	+30	1	37	5	−12	105	1065
3	+30	4	41	6	−13	91	1156
4	+17	4	45	7	−13	105	1261
5	+20	2	47	8	−15	133	1394
6	+25	6	53	9	−17	92	1486
7	+16	12	65	6.0	−17	156	1642
8	+15	12	77	1	−21	65	1707
9	+18	10	87	2	−20	52	1759
3.0	+10	9	96	3	−21	58	1817
1	+11	10	106	4	−22	38	1855
2	+13	10	116	5	−23	55	1910
3	+08	9	125	6	−29	20	1930
4	+13	16	141	7	−27	51	1981
5	+12	16	157	8	−33	44	2025
6	+10	13	170	9	−31	44	2069
7	+06	15	185	7.0	−31	51	2120
8	+05	22	207	1	−31	36	2156
9	+08	18	225	2	−32	27	2183
4.0	+07	24	249	3	−32	30	2213
1	+02	37	286	4	−28	20	2233
2	+01	29	315	5	−28	12	2245
3	+04	28	343	6	−30	11	2256
4	00	41	384	7	−31	8	2264
5	+02	31	415	8	−37	6	2270
6	−01	48	463	9	−37	3	2273
7	−03	39	502				
8	−03	49	551	8.3	(−16)	10	2283
9	−05	52	603				

of naked eye estimates. The rate of variation is closely 0.11 per unit of magnitude. This inclined line corresponds to a consistent difference of unit light ratios in the two scales of magnitude.

No direct derivation of values of unit light ratio can be made from the summations, since the two catalogues include not only all the stars to grade 5.9 in the area —22° declination to the south pole but also a large number of southern stars north of that area. The counts would indicate that nearly all

the stars to fifth magnitude in the southern sky are embraced in this comparison. From earlier computations the deduced light ratio of the P. G. C. is close to 2.0,[1] while that of San Luis is 2.2.[2] The light ratio of the photometric scale is thus about 0.2 greater than that of the Historic visual scale, down to seventh magnitude. While it may not be possible to derive absolute figures that will be accepted without question, by this method of computation, the relative figures are quite definite.

The average probable error of a difference of magnitude is ± 0.06, smaller in the groups of bright stars and larger in the groups of faint stars. Single residual differences of 0.4 or larger have been omitted in computing the means. The total omissions were 24, or one in a hundred comparisons; but only 8 of the omissions were for stars brighter than sixth-magnitude, or one in two hundred.

The Preliminary General Catalogue of Boss includes 6188 stars, distributed through the whole sky. The San Luis Catalogue of the Carnegie Institution of Washington includes 15333 stars, nearly all of which are south of the equator.

Palo Alto, Calif.
May, 1933.

[1] *Pub. Astr. Soc. Pac.*, 41, 177, 1929.
[2] *Pop. Astr.*, 39, 463, 1931.

AMERICAN EUSMILOID SABRE-TOOTH CATS OF THE OLIGOCENE EPOCH

GLENN L. JEPSEN

(*Read by title, April 21, 1933*)

THE four skulls of *Eusmilus* which are described in this paper illustrate the apparently rapid evolutionary drift of this rare sabre-tooth cat genus during its recognized range through the Brule formation of the White River middle Oligocene series. *E. sicarius*,[1] the lower Brule species, was a small but already highly specialized type; and the upper Brule form, *E. dakotensis*,[2] heretofore represented by a single lower jaw, reached dimensions within the size limits of the Pleistocene *Smilodon* and had sabre-teeth larger in proportion to skull size than in any described specimen of the latter.

The suggestion that *Eusmilus* and contemporary Brule Hoplophonids emerged from *H. oharrai* of the Chadron formation underlying the Brule (see Fig. 1), or from a similar form with very deep jaw flanges, has been revived by a restudy of the type of the latter species during its comparison with a complete skeleton which was collected by the 1932 Scott Fund expedition. The difficulties of interpreting the evidence which supports this proposal are manifold even when the European *Eusmilus* is omitted from consideration. In nearly every respect, however, in which *E. sicarius* differs from typical Brule *Hoplophoneus*, *H. oharrai* presents an intergraded combination or modification of the divergent characters.

All of the known American specimens of *Eusmilus* and of *H. oharrai* have been gathered together for this comparative study, and the author is indebted to Mr. C. W. Gilmore of

[1] Sinclair, W. J., and Jepsen, G. L., "The Skull of Eusmilus," *Proc. Am. Phil. Soc.*, Vol. LXVI, 1927, pp. 391–407, Figs. 1–8.

[2] Hatcher, J. B., "Discovery, in the Oligocene of South Dakota, of Eusmilus, a Genus of Sabre-toothed Cats New to North America," *Am. Naturalist*, 1895, pp. 1091–1093, Pl. XL.

the U. S. National Museum, to Dr. C. C. O'Harra of the South Dakota State School of Mines, and to Mr. C. Bertrand Schultz of the Nebraska State Museum, who have submitted material for determination and description from their respective institutions.

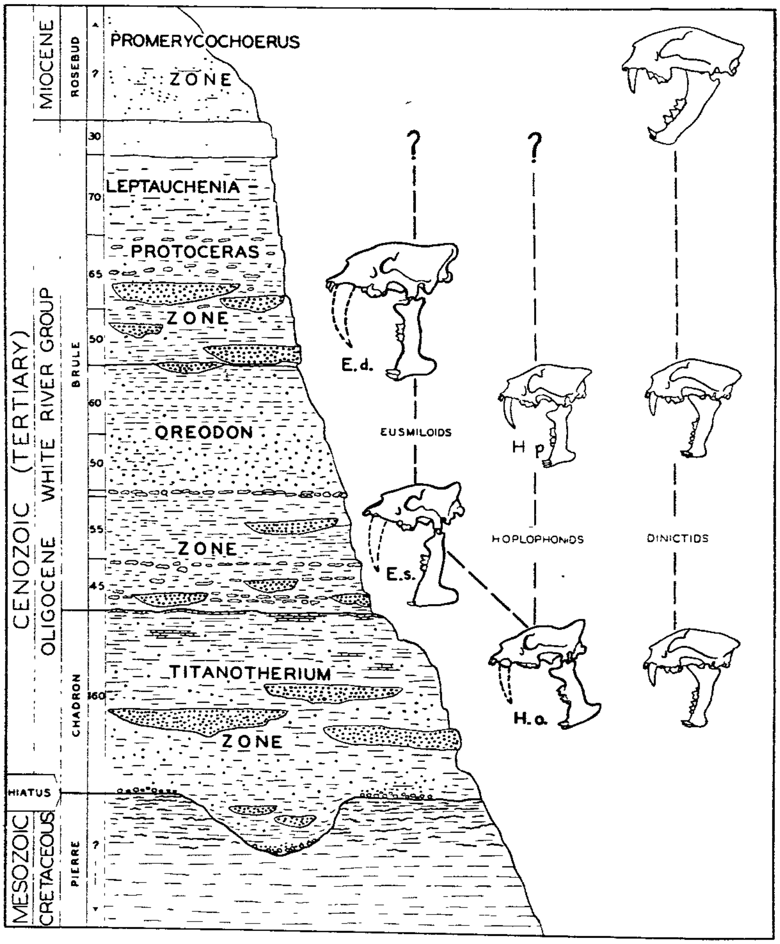

FIG. 1. Diagram showing the range of *Eusmilus* through the Brule formation of the White River Group, and suggesting the derivation of the genus from *Hoplophoneus oharrai* (H. o.), in the Chadron formation. E. s., *Eusmilus sicarius;* E. d., *Eusmilus dakotensis;* H. p., *Hoplophoneus primævus.* Outlines drawn to scale to indicate relative size.

The descriptions and speculations in this paper result from the desire to make the new material available for future study. Oligocene and Pleistocene sabre-tooth felids are now abundantly represented in many museums, but only a few specimens have been collected from the Miocene and Pliocene sediments. Until more are discovered, conjectures about the phylogeny of the Machærodonts during this gap of two epochs seem futile. Especially is this true in light of the skillful observations of Merriam and Stock [1] in describing the wide individual variation range of specimens of *Smilodon californicus*. A similar critical restudy of the available specimens of *Hoplophoneus* would almost certainly reduce the number of species within the genus.

Collections of skulls and jaws of modern species, subspecies, and geographic races or varieties of lions, tigers, and jaguars have been examined by the author in preparation for this study. These specimens of large living felids vary within each species to limits which would be classified as several species if the customary distinctions between fossil cats were used as criteria and the intergraded individuals omitted. In addition to the difficulties which this fact imposes upon a satisfactory and usable conception of extinct species that are known from only a few or from single specimens, the complicating element of sequence in time must be considered. Other unfortunate necessities in the manufacture of fossil species from inadequate material are the comparisons of individuals in different stages of development and of different sexes.

As gaps in the ancestral record are filled, contemporaneous as well as descendant species are welded by overlapping characters until the boundaries disappear. If the concerted modern opinion of paleontologists about the nature of species is correct, classification units are satisfactory only so long as each group of individuals remains sufficiently separated from other groups by the possession of describable, unique characters. If new species emerge from old by the slow gradual

[1] Merriam, J. C., and Stock, C., "The Felidæ of Rancho La Brea," Carnegie Institution of Washington, Publication No. 422, 1932.

accumulation of minute individual variations, instead of by sudden saltations, taxonomic units will become more highly arbitrary and artificial as more "missing links" are found.

The principle of slow amassment of new or modified skeletal structures is one of the theses of evolution. The changes are ultimately discernible to the paleontologist as clusters of specific characters. This conception is frequently illustrated by hypothetical phylogenies founded upon time sequences of species whose validity, however, is vitiated with approaching completeness of the record. "Family trees" are usually drawn with the species discretely separated by bare spaces or leafy mysteries. For graphic presentation this practice can be defended, but it confuses the inquiring scholar who would attempt to visualize the complex development and distribution of fossil species. Even modern biological species are sometimes difficult to define, but the greater problems of a practicable paleontologic nomenclature become increasingly apparent and irksome as the time gaps between genera and species are filled by new discoveries.

The snug fit of many specific descriptions hinders any attempt to include closely related individuals. Frequently, if the use of a specific name were restricted to specimens identical with the holotype, the latter would remain the sole entitled occupant of the species. This is particularly true of those groups that show rapid and wide individual variation, such as the Oligocene Titanotheres. In some instances, species have been manufactured so lavishly that the rising mountains of synonomy discourage ascent.

The practice of referring to supposed evolutionary sequences as "strains" or "temporal races" implies a subtlety of distinction which is difficult to maintain. The material at hand illustrates this.

New, widely applicable, and flexible principles for the founding of fossil species may become necessary. If so, isolated specific instances of observed facts, such as those which the author attempts to describe in this paper, may be of service in formulating the new devices. There is no intent

here to champion a cause, but to express individual concern about the future insecurity of the present drowsy comfort of attempting feats with a taxonomic mechanism not designed for such purposes.

Taxonomists with whom the author has conversed about the limitations of the binomial system have declared, without exception, that the present application of the system lacks flexibility and portrays an untrue picture of species, although it serves adequately for the designation of isolated specimens which are only remotely related to others. Hence, this paper lays no claim to originality, but merely illustrates again the difficulties encountered in using the present tools to fashion a satisfactory conception of the relationships of a very small group in a restricted time range. This simple analysis of a few specimens may lack much in the "proof" of any contentions, but it contains abundant desire to see the problems faced and pondered.

Perhaps some of the suggestions about numerical or directional classification schemes of Hoffmeister [1] or others [2] who have become concerned about the limitations of Linnæus' system can be adapted with advantage to the taxonomy of fossil mammals.

As others have pointed out, numerical indicators lack self-contained meaning and mental appeal. Although the use of numbers permits greater freedom in indicating the systematic position of intergraded forms, such a scheme could not be readily superposed upon the present gigantic mammalian classification.

Some of the widely recognized difficulties which have been mentioned above are apparent in the analysis of *Eusmilus* that follows.

[1] Hoffmeister, J. E., "The Species Problem in Corals," *Am. Jour. Sci.*, 5th Ser., Vol. XII, pp. 153–156, 1926.

[2] Bernard, H. M., "The Unit of Classification for Systematic Biology," *Proc. Camb. Phil. Soc.*, Vol. II, pp. 268–280, 1901. Trueman, A. E., "The Species Concept in Paleontology," *Geol. Mag.*, Vol. 61, pp. 355–360, 1924.

Eusmilus dakotensis Hatcher

(1) Holotype, Princeton No. 11,079. Complete right ramus with broken canine and lacking I_1. From a *Protoceras* channel sandstone, upper Brule formation, badlands, south of White River, South Dakota. Described and figured in *The American Naturalist*, Vol. XXIX, pp. 1091–1093, Pl. XL, 1895.

(2) Allotype, South Dakota State School of Mines No. 2815. Plate IV. Complete adult skull with only two teeth preserved, left I^3 and right P^3. Same horizon as holotype.

(3) Referred specimen, South Dakota State School of Mines No. 2830. Crushed and poorly preserved adult skull. Lacks all incisors, right canine and molar. Same horizon as holotype.

(4) Referred specimen, Nebraska State Museum No. 6–12–7–95. Incomplete left half of skull, lacking posterior part but with well preserved facial region, slightly crushed. Zygomatic arch and glenoid pedicle complete. Lacks I^{1-2}, otherwise dentition of left side is complete. Unfused sutures and condition of teeth indicate a young adult individual. Although this specimen has no record other than "Oligocene badlands of S. Dak.," some adhering coarse sandstone matrix is fairly good evidence that it also was collected from a *Protoceras* channel.

Eusmilus sicarius Sinclair and Jepsen

(5) Holotype, Princeton No. 12,953. Complete, somewhat crushed adult skull; left canine missing and right canine broken off in socket. Complete right ramus, with broken canine. Fragments of left ramus. From lower Brule "red layer," 8.5 miles south of Wall, Pennington County, South Dakota. Described and figured in the *Proceedings*, *Am. Phil. Soc.*, Vol. LXVI, pp. 391–407, figs. 1–8, 1927.

(6) Referred specimen, U. S. Nat. Mus. No. 12,820. Plates

II and III. Well preserved skull of young individual, lacking all incisors except right I^1, with milk canines and incoming permanent canines. Both zygomatic arches broken. Left side of skull slightly crushed. Fragments of both lower jaws. Atlas, axis, 5th, 6th, and 7th cervical, and two lumbar vertebræ. Parts of left forelimb, including scapula, distal end of humerus, proximal ends of radius and ulna, and distal end of radius, lacking most of the epiphyses. Specimen from "N.W. corner Seaman Hills, Niobrara County, Wyo., Brule formation," Oreodon beds, probably above the level of the holotype.

The following characters of *Eusmilus* are selected as being of particular significance in separating the genus from the most similar coeval form, *Hoplophoneus:*

1. Dental formula $I\,\frac{3}{3(2)},\ C\,\frac{1}{1},\ P\,\frac{(3)2}{1},\ M\,\frac{1}{1}$.

2. Very large, flattened, superior canines or "sabre-teeth."

3. Elongate facial region.

4. Stout, straight, zygomatic arches.

5. Long glenoid pedicle.

6. Very deep chin flange.

7. Long diastema between lower canine and P_4.

8. Progressive reduction of M_1 to two shearing blades without heel.

Each of these distinctions will be amplified and explained in terms of contrast with *Hoplophoneus*.

(1) Removal of some matrix from the type jaw of *E. dakotensis*, medial to I_2, reveals a diastema of about 3 mm. between this tooth and the symphysial surface, and a deep pit which was probably occupied by I_1. Unfortunately, Hatcher did not see this alveolus, but he placed little emphasis upon the supposed reduction of incisors. The corresponding region of *E. sicarius* shows evidence of only two incisors [1] but the preservation is rather poor.

[1] Sinclair, W. J., and Jepsen, G. L., "The Skull of Eusmilus," *Proc. Am. Phil. Soc.*, Vol. LXVI, p. 392, 1927.

U. S. Nat. Mus. No. 12,820, skull of a young individual, referred to *E. sicarius*, retains a small single-rooted peg-like P^2 on the left side (see Plate III), closer to the milk canine than to P^3, with no trace of a corresponding right tooth. All other Eusmilids lack P^2. P^2 is present on both maxillæ, either single or double rooted, of all the specimens of *Hoplophoneus* in the Princeton collection, except No. 11,372 (*H. insolens* ?) which lacks the left one, and is invariably adjacent to P^3. These observations indicate that P^2 is a small, variable ("vestigial") structure to which no generic significance can be attached, but it appears more consistently in *Hoplophoneus* than in *Eusmilus*. Furthermore, the only P^2 upon four skulls of the latter genus is aberrantly situated. In terms of genetics, it may be inferred that the "factor" for P^2 declined in expression in both strains, but was more persistent in *Hoplophoneus* than in *Eusmilus*.

Hence, the only consistent difference in dental formula between *Eusmilus* and *Hoplophoneus* is that the former, both in Europe and North America, had one less lower premolar. Three jaws, left and right of the holotype of *E. sicarius*, and the holotype of *E. dakotensis*, are well enough preserved to show the absence of P_3. The suggestion that they are consistently abnormal introduces unwarranted caution, although P_3 varies in development in related groups of cats. This slight inferior dental disparity alone might be insignificant, but it fails to indicate the far more important differences of proportion, cuspidation and attitude of the teeth, all of which have been previously described.[1]

(2) The upper canines of *Eusmilus* are very large and flat, having an antero-posterior diameter much greater than that of any measured *Hoplophoneus* (see Table I). Observe in the "canine diameter" ratios that the transverse diameter of the canine alveolus is more than 49 per cent of the antero-posterior diameter in all Brule *Hoplophoneus* except No.

[1] Hatcher, J. B., "Discovery in the Oligocene of South Dakota of Eusmilus, a Genus of Sabre-toothed Cats New to North America," *The American Naturalist*, Vol. XXIX, p. 1091, 1895. Sinclair, W. J., and Jepsen, G. L., "The Skull of Eusmilus," *Proc. Am. Phil. Soc.*, Vol. LXVI, 1927, pp. 391–407, figs. 1–8.

TABLE I

SKULL MEASUREMENTS, IN MILLIMETERS, AND INDICES OF *Eusmilus* AND *Hoplophoneus*; "a" INDICATES AN APPROXIMATE MEASUREMENT OR A MEAN BETWEEN THE LEFT AND RIGHT SIDES

	Eusmilus sicarius. Holotype, P.U. No. 12,953	*E. sicarius.* Referred spec., U. S. Nat. Mus. No. 12,820	*E. dakotensis.* Allotype, S.D.S.M. No. 2815	*E. dakotensis.* Referred spec., S.D.S.M. No. 2830	*E. dakotensis.* Referred spec., Neb. State Mus. No. 6-12-7-95	*Hoplophoneus oharrai.* Holotype, S.D.S.M. No. 2417	*H. oharrai.* Referred spec., P.U. No. 13,593	*H. oreodontis.* P.U. No. 13,628	*H. oreodontis.* P.U. No. 10,515	*H. primævus* (immature). P.U. No. 10,540	*H. primævus.* P.U. No. 12,730A	*H. primævus.* P.U. No. 13,136	*H. robustus.* P.U. No. 12,749	*H. robustus.* P.U. No. 10,647	*H. robustus.* P.U. No. 12,957	*H. insolens.* P.U. No. 11,372	*H. insolens.* P.U. No. 12,590
1. Prosthion–basion	187	211a	251	238a		185		137	130.5		156	155	163		179	177	179
2. Prosthion–inion	198.5a	218.5	294.5			206a		158	144a				184		200	206	216
3. Prosthion–bregma	142a	165	208.5			129		108.7	101.4	115	117	117	127	134	130.2	131.5	
4. Prosthion–post. edge C. alveolus	48a	58.5	70.7	56a	61a	43.7a	38.7	29.6	25	36.7	32.5	32.4	32	38	36	33	33
5. Prosthion–ant. edge P^3	69a	81a	86.5	77a	81a	59a	62.5	41	36	46	47	46.5	49	51	52	55.3	51
6. Ant.-post. diam. C. alveolus	32	33	46	34.2	40.5	22	16.7	11.7	11.8	16.4	15.7	15.7	14		16.8	17.5	
7. Transverse diam. C. alveolus	6	8.5a	13.7	13.1	15.3	9	7.8		7	5.1	7.8		7.7		10.5	8.8	
8. P^3–M^1	36	41.8	47	45.3	43.5	38	38.5	30.5	29.6	35.7	33.5	35.6	35a	41.5	37.6	37.3	43.5
9. Ant.-post. diam. P^3	9	11.4	12.6	12.7	12.6	12	10.7	10	9.7	11	11.7	12	11	12	11.5	12	14
10. Ant.-post. diam. P^4	22.5	22	32.6a	27.8	29.6	19	20.2	17.6	17.3	19.9	19.6	19.4	17.5	19	19.7	20.5	21.3
11. Palatal length (after Eaton)	115a	120	129	122a	124a	101a	98a	75	62	74	77	76.5	78	87	87	86	86
12. Diam. of postorbital processes		76	91		86	64		57.5	56a	60a	70a	63a			70a	76.2	81
13. Diam. of postorbital constriction		36.3	41			27.5		28	27.8	32	32.3	28	31.8		33.4	35.1	36
Ratios																	
1. Facial (5/1 × 100)	36.9	38.4	34.5	32.3		31.8		29.9	27.6		30	30	30		29	31.2	28.5
2. Canine diameter (7/6 × 100)	18.7	25.8	29.8	38.3	37.8	40.8	46.7		59.3	31.1	49.7		55		62.5	50.3	
3. Palatal (11/1 × 100)	61.5	56.8	51.5	50.8		54.5		54.7	47.5		49.4	49.3	47.8		48.5	48.5	48
4. Postorbital process (12/1 × 100)		36	36.2			34.6		42	43		44.9	40.6			39.1	43	45.2
5. Postorbital constriction (13/1 × 100)		17.4	16.6			14.8		20.4	21.3		20.6	18.1	19.5		18.7	19.8	20.1

10,540, which has a milk sabre that is excessively narrow to accommodate the incoming permanent canine. The canine diameter ratio in *Eüsmilus* is from 18.7 to 38 and from 40.8 to 46.7 in *H. oharrai.*

(3) *Eusmilus* has a longer facial region, in proportion to skull length, than *Hoplophoneus.* Points of measurements to illustrate this feature are difficult to choose, although it is easily demonstrated by comparison of the specimens themselves. The "palatal ratios" in Table I show that the distance from the prosthion to the anterior edge of P^3 varies from 32.3 per cent to 38 per cent of the basal length of the skull in *Eusmilus,* and from 27.6 per cent to 31.2 per cent in Brule *Hoplophoneus. H. oharrai* here again intergrades with its ratios of 31.8. A further illustration of the comparatively long face of *Eusmilus* can be read from the measurements of Table I, lines 4 and 8; *i.e.*, the length of the cheek teeth series P^3-M^1 is less than the distance from the prosthion to the posterior border of the canine alveolus in *Eusmilus,* and more in *Hoplophoneus,* with the sole exception of the young individual No. 10,540.

(4) The zygomatic arch of *Hoplophoneus,* in palatal view, curves outward and backward from the maxillary pedicle and inward to the glenoid pedicle, with the maximum expanse, or rise, of this smooth, regular curve anterior to the glenoid fossa. *Eusmilus*' arch, in similar aspect, makes an almost straight bar connecting the maxillary and the glenoid pedicles, with the broadest flare lateral to the glenoid fossa. This very singular and consistent straightness of the arch was at first believed to be the result of crushing, but the arches are flat even on the skulls which show no signs of distortion in that region. Due to the lateral curve of the arch in *Hoplophoneus,* the maximum distance between it and the sphenoid is greater than that from the posterior palatine border to the anterior rim of the glenoid fossa. In *Eusmilus* the latter distance is the greater.

(5) The glenoid pedicle is comparatively very long in *Eusmilus.* This, with the great dorso-ventral height and

TABLE II

JAW MEASUREMENTS, IN MILLIMETERS, AND INDICES OF *Eusmilus* AND *Hoplophoneus*

	Eusmilus sicarius. Holotype, P.U. No. 12,953	*E. dakotensis.* Holotype, P.U. No. 11,079	*Hoplophoneus oharrai.* Holotype, S.D.S.M. No. 2417	*H. oharrai.* Referred spec., P.U. No. 13,593	*H. oharrai.* Referred spec., P.U. No. 13,635	*H. mentalis.* Holotype, P.U. No. 12,515	*H. oreodontis.* P.U. No. 13,628	*H. primævus.* P.U. No. 10,540	*H. primævus.* P.U. No. 11,013	*H. primævus.* P.U. No. 13,136	*H. robustus.* P.U. No. 12,749	*H. robustus.* P.U. No. 10,647	*H. insolens.* P.U. No. 12,590
1. Overall length. Ant. end symphysis–post. end	167	173	150	147	136	145	112		116	123.4	130	134.5	142a
2. Flange depth. Post. border C. alveolus to tip	91	79	76.4		57	62.5	38a			39a	45	50a	57a
3. Diastema C–P_4	58.5	54	50	47.4	35.7	41.8	28a	29	30a	36.6	39	39a	39.5
4. P_4–M_1	31	39.4	30	30.5		29.2	25.5	30.8	31	29a	28	30.6	33.5
5. Depth ant. to cheek teeth	33	32	30		26.7	25.8	21.4	25.3	21a	23.3	25.5	26.7	26
6. Depth under P_4	34	36	34			26.6	19.4	22	21	24	24.1	26.6	26.2
7. Depth post. to M_1	27.5	31.5	26.8		26	22.5	20	21	18	19	22	26	24.6
8. Coronoid height (above tangent from top of condyle to base of M_1)	14.3	24	27.8			21.2	17a		17	20a	17	15a	17.5
9. P_4 length	11.5	16	11	11.8	12.4	12.7	9a	11.6	12.8a	11a	11	13.5a	
10. M_1 length	19.5	23	17	18.6		17.5	16a	18	17.3a		15.8	16.5	
Ratios													
1. Flange depth (2/1 × 100)	54.5	45.7	50.9		41.9	43.1	33.9			31.6	34.6	37.2	40.2
2. Diastema (3/1 × 100)	35	31.2	33.3	32.2	26.2	28.8	25		25.8	29.6	30	29	27.8

massiveness of the arch, gives the posterior surface of the pedicle a notable quadrangular shape in contrast to the truncated triangular form of this area in *Hoplophoneus*. These interrelated structural factors may be modifications in an extreme specialization for stabbing with the huge canines.

(6) Great depth of chin flange was one of the features which appeared to Hatcher to be of great significance in *E. dakotensis*. This character still has generic value. Table II shows that the ratio of chin flange (posterior border of canine alveolus to tip of flange) to overall jaw length is from 45.7 to 54.5 in *Eusmilus*, 31.6 to 40.2 in Brule *Hoplophoneus*, and 41.9 to 50.9 in the Chadron *Hoplophoneus*.

(7) The length of the diastema between the lower canine and P_4 is from 31.2 per cent to 35 per cent of the total length of jaw in *Eusmilus*, whereas a corresponding ratio in *Hoplophoneus* specimens from the Oreodon beds varies from 25 per cent to 30 per cent. *Hoplophoneus oharrai*, again intergraded, gives a ratio of 26.2 to 33.3. The alveolar border between the canine and P_4 of *Eusmilus* is thin and sharp, and "curves abruptly downward in front of the premolar, but rises rapidly beyond and continues forward as a sharp ridge which curves inward and then outward toward the canine." [1]

(8) Progressive reduction of the heel of the lower molar of *Eusmilus* has been discussed previously,[2] and no new data can be added now.

Many other characters could be cited as generic criteria, but some of them require a detail of description beyond the limits of this paper. Two more may be mentioned, however, for future comparisons.

(9) The lateral surfaces of the maxillæ are constricted, or notched, back of the pronounced canine bulge on the face of *Hoplophoneus*, whereas the corresponding region of *Eusmilus* is comparatively plane.

(10) The postorbital constriction of *Eusmilus* is farther back of the postorbital processes than it is in *Hoplophoneus*.

[1] Sinclair, W. J., and Jepsen, G. L., "The Skull of Eusmilus," *Proc. Am. Phil. Soc.*, Vol. LXVI, 1927, p. 405, fig. 6.

[2] *Ibid.*, p. 394.

Specific Characters of *E. sicarius* and *E. dakotensis*

Although there are great differences between the two species of *Eusmilus*, the selection of significant and usable distinctions is difficult because the material represents both old and young specimens, and, perhaps, different sexes.

The adult skull (P.U. No. 12,953) from the lower Brule is much smaller than the upper Brule skull (S.D.S.M. No. 2815); but the other skulls (U. S. Nat. Mus. No. 12,820, S.D.S.M. No. 2830, and Neb. State Mus. No. 6–12–7–95) partially interpolate characters of size and structure.

The species *E. dakotensis* has been heretofore solely occupied by the type jaw, and the reference here of the upper Brule skulls to this species is a tentative suggestion now supported by much evidence which may prove untenable if and when associated skulls and jaws are found.

The following features of *E. dakotensis* are given in terms of contrast to corresponding structures in *E. sicarius:*

1. Larger size. See Table I for dimensions.
2. Larger mastoid processes. Compare Plates II and IV.
3. Straighter sagittal crest.
4. Reduced heel of M_1, and other jaw characters which are indicated in the description of the holotype of *E. sicarius*.

Additional distinctive features of *E. dakotensis* which merit mention are the enlargement of the glenoid pedicle, the great size of the canines, and the massiveness and shortness of the zygomatic arch.

All of these characters which distinguish *E. dakotensis* are merely exaggerated developments which were already incipient or rudimentary in *E. sicarius* where, in turn, they were apparently modified from an ancestral stock like *H. oharrai*.

Before a skull of *Eusmilus* was found, the possibility had been suggested that the genus might have been derived from certain species of *Hoplophoneus*, with very deep jaw flanges, from the underlying Titanotherium beds.[1] With the first

[1] Sinclair, W. J., *Proc. Am. Phil. Soc.*, Vol. LX, No. 2, 1921. Jepsen, G. L., "The Oldest Known Cat, Hoplophoneus oharrai," *The Black Hills Engineer*, Vol. XIV, No. 2, 1926, p. 91.

description of the skull, that speculation seemed less probable, but now that all the critical material, both old and new, has been assembled for comparison, the presumption is again revived. If and when the skull of the old world *Eusmilus*, now known only from jaws and teeth, is found, the referred American types may be relegated to another genus. Kretzoi, in his ambitious revision of the classification of the felids in 1927,[1] favored including the White River *Eusmilus* within *Hoplophoneus*. This conclusion, however, was based upon Hatcher's analysis of the type jaw of *E. dakotensis*, and without knowledge of the unique characters of the skull and its marked contrast to that of contemporary Hoplophonids.

A note may be added here about the jaw which was described as *Eusmilus whitfordi*[2] from the Pliocene of Nebraska. Sinclair and Jepsen[3] advised its removal from the genus, and Burt has recently suggested its retention. A cast of the jaw reveals few characters in common with the type jaws of *E. sicarius* and *E. dakotensis*, but great differences. It has a relatively small chin flange, retains P_3, and has a short diastema between this tooth and the canine. These are three features away from the direction of specialization of *Eusmilus* and beyond which it had drifted by middle Oligocene time.

Summary

The above group descriptions of the four skulls of *Eusmilus* and the definitions of the two species within the genus, *sicarius* and *dakotensis*, demonstrate the rapid evolutionary changes of *Eusmilus* from lower to upper Brule times.

The outline of characters which delimit *Eusmilus* from the contemporary species of *Hoplophoneus* also suggests the derivation of both forms from an earlier type like *Hoplophoneus oharrai* (Plate I) from the Chadron formation. The

[1] Kretzoi, N., "Materialen zur phylogenetischen Klassifikation der Aeluroideen." Xe Congrès International de Zoologie tenu à Budapest (Sept. 4–10, 1927), pt. 2, pp. 1293–1355.

[2] Barbour, E. H., and Cook, H. J., "A New Sabre-toothed Cat from Nebraska," *Nebraska Geol. Survey Publications*, Vol. 4, Part 17, pp. 235–238, Pl. I, 1915.

[3] Sinclair, W. J., and Jepsen, G. L., "The Skull of Eusmilus," *Proc. Am. Phil. Soc.*, Vol. LXVI, pp. 391–407, figs. 1–8, 1927.

latter species combines structures of Brule Eusmiloids and Hoplophonids to such an extent that its generic assignment is arbitrary.

The present classification system cannot indicate any of these suggested relationships and hence, by itself, fails to reveal certain speculations and implies an exaggerated finality of others.

PRINCETON UNIVERSITY, PRINCETON, NEW JERSEY,
THE WILLIAM BERRYMAN SCOTT RESEARCH FUND.

PLATE I

PLATE I. Skull of *Hoplophoneus oharrai*. Holotype. S. Dak. State School of Mines No. 2417. 2/3 natural size.

PLATE II

PLATE II. Skull of *Eusmilus sicarius* (?). Referred specimen. U. S. Nat. Mus. No. 12,820. Young individual with milk and permanent canines in place. 2/3 natural size.

PLATE III

PLATE III. Skull of *Eusmilus sicarius* (?). Referred specimen. U. S. Nat. Mus. No. 12,820. Palatal view. Note incoming permanent canines. 2/3 natural size.

PLATE IV

PLATE IV. Skull of *Eusmilus dakotensis*. Allotype. S. Dak. State School of Mines No. 2815. 1/2 natural size.

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